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Bulletin 190

DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

BUREAU OF MINES
H. FOSTER BAIN, Director

COAL-MINING PROBLEMS IN THE STATE OF WASHINGTON

BY

GEORGE WATKIN EVANS

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CONTENTS.

Page.

- Introduction 1
  - Acknowledgments 2
  - General statement 3
- Western Washington 3
  - Thurston, Lewis, and Cowlitz Counties 3
    - Subbituminous coal areas 3
      - Topography 3
      - Geologic structure 5
      - Stratigraphy 5
      - Character of the coals 5
      - Mining methods at the Tono mine 5
        - Geology and topography of district 5
        - Slopes and rooms 7
        - Pillar drawing 8
        - Blasting methods 8
        - Haulage and hoisting 8
        - Ventilation 8
        - Timbering 9
        - Drainage 9
        - Preparation of coal 9
    - Bituminous coal area 9
    - Mining methods in Lewis County 10
      - Openings 10
      - Relation of dip to system of mining 11
      - Effects of inclosing strata 11
      - Details of room and pillar systems 11
        - Plane system 12
        - Chute and pillar system 13
        - Blasting 14
        - Ventilation 14
        - Mine fires 14
        - Preparation of coal 15
  - Whatcom and Skagit Counties 15
    - Bellingham mine, Whatcom County 15
  - King County 16
    - Subbituminous district 16
    - Raging River district 17
    - Cedar River district 18
    - Green River district 18
      - Kummer series 19
      - Franklin series 19
      - Bayne series 19
      - Beds of the Green River district 20

Western Washington—Continued.
King County—Continued.
Green River district—Continued.

Page.
Mines of the Green River district 20
Ravensdale mine 20
Black Diamond, Franklin, Cannon, Hyde, and Kummer mines 20
Kangley, Hiawatha, Durham, Occidental, National, and Pocahontas mines 21
Kinds of coal in King County 22
Forms of openings 22
Surface transportation 22
Mining operations in King County 23
Gangways 23
Tunnels 24
Slopes 24
Plane system 26
Chute and pillar system 27
Breast and pillar system 28
Pillar drawing in breast and pillar workings 30
Special chute and pillar system 32
Longwall system 35
Surface subsidence and drainage 35
Underground waters 37
Underground haulage 38
Mining and blasting 39
Timbering 39
Ventilation 40
Overcasts 40
Stoppings and air deflectors 40
Doors 40
Mine fires 42
Man cars 42
Pierce County 42
Carbon River district 42
Topography 42
Structure 43
Stratigraphy 44
Burnett formation 44
Wilkeson formation 44
Carbonado formation 45
Melmont formation 45
Fairfax mine 46
Montezuma mine 46
Nisqually district 46
Mining methods of Pierce County 47
Quality of coal 47
Forms of openings 48
Surface transportation 48
General plan of working 48
Breast and pillar system 49
Special breast and pillar system 50
Chute and pillar system 51
"Booming" system 54
Longwall method 55

Western Washington—Continued.
Pierce County—Continued.
Mining methods of Pierce County—Continued.

Page.
Blasting 57
Preparation 57
Timbering 57
Mine fires 57
Ventilation 57
Overcasts 58
Stoppings 58
Doors 58
Eastern Washington 58
Kittitas County 58
Topography 59
Stratigraphy 60
Structure 60
Output from Roslyn bed 60
General conditions in Kittitas County 61
Surface haulage 61
Mining methods 61
Gangways or entries 63
Rooms 64
Cutting the coal and shot firing 65
Pillar drawing 66
Timbering 66
Haulage 66
Ventilation 67
Lighting 67
Costs 67
Production 67
Preparation 68
Lewis County 69
Subbituminous district 69
Kittitas County 69
Subbituminous district 69
Labor 69
Supplies 70
Fixed charges 70
King County 70
Subbituminous district 70
Labor 70
Supplies 70
Fixed charges and general expenses 70
Bituminous district 71
Labor 71
Supplies 71
Salaries and general expenses 71
Pierce County 71
Coking bituminous coal 71
Labor 72
Supplies 72
Fixed charges 72
Tables 72
Accidents in Washington coal mines 73
Publications on coal-mining methods 76

TABLES.

Page.

Table 1. Scale of day wages paid in Washington coal mines (inside mine) 72
2. Scale of day wages paid in Washington coal mines (outside mine) 73
3. Number of tons per man per day for the coal-mining counties of Washington for the years 1913 to 1918 73
4. Percentage of increase or decrease in output per man per day since 1913 73
5. Number of hours worked in and about coal mines in Washington, and the fatality rate based on the number of 2,000-hour workers 74
6. Number of hours to the working day, by years, in and about the coal mines in Washington 74
7. Coal-mine accidents in Washington, in which five or more men were killed 75
8. Fatalities due to dip or pitch of coal seams in Washington mines, 1905 to 1917 75
9. Fatalities in Washington coal mines, by principal causes, during the years 1914 to 1917 and for the 29-year period 1887 to 1917 75

ILLUSTRATIONS.

Page.

PLATE I. Sketch map of western Washington, showing coal areas, principal cities, and lines of transportation 2
II. Outline of King County, showing situation of several coal districts, position of mines, and lines of transportation 16
III. Stratigraphic relationship of coal beds mined at Franklin, King County 17
IV. Stratigraphic relationship of coal beds at Coal Creek, King County 20
V. General plan of mine using breast and pillar system 29
VI. Structural relationship of coal beds mined at Burnett, Pierce County 47
VII. Map of Roslyn coal field, showing known and probable extent of Roslyn beds, also location of mines 58
FIGURE 1. Outline map of Thurston and Lewis Counties showing position of coal areas, names and situation of mines, and lines of transportation 4
2. Plan of Tono mine, working a 17-foot subbituminous bed 6
3. Details of room and entry in Tono mine 7
4. Room and pillar method employed in a Lewis County mine 12
5. Method of working a 11-foot bed 13
6. Method of timbering in gangway, strong roof 23
7. Method of timbering in gangway, weak roof 24
8. Method of timbering in gangway, strong roof that scales off 24

Page.
FIGURE 9. Method of slope development used in coal bed 5 feet 8 inches thick 25
10. Cross section of double compartment slope, showing method of timbering 26
11. Chute and pillar system of working a 25-foot bed of bituminous coal 27
12. Elevation showing method of timbering gangway and chute in coal bed with shale walls 29
13. One way of ventilating a gangway and first counter faces 30
14. Method of working coal bed 5 feet 8 inches thick 31
15. System used when mining with Sullivan post punchers in 70-foot breasts 32
16. Breast and pillar system of working a 6-foot bed 33
17. Special chute and pillar system 34
18. Panel longwall system for coal beds 6 feet thick 36
19. Method of ventilating three beds that are being worked simultaneously 41
20. Outline map of Pierce County, showing coal areas, situation of mines, and lines of transportation 43
21. Location of gas outbursts in Wingate mine 51
22. Ineffective method of working with rock gangway and rock chutes, tried in gaseous district, Carbonado mine 52
23. Chute and pillar system used in working 11-foot coal bed, Wilkinson mine 53
24. Opening out a long-wall face in a coal bed 55
25. Long-wall face in coal bed 56
26. Map of Kittitas County, showing Roslyn-Cle Elum, Taneum, and Manastash coal fields and transportation lines 59
27. One method of working Roslyn bed in Roslyn field 62
28. Method of sinking single slope, Roslyn bed 63
29. One method of driving gangway or entry, Roslyn bed 63
30. One method of holing-in, in driving gangways or entries, Roslyn bed 63
31. One method of mining rooms, using cars to face 64
32. Detail of sheave, or "McGinty," and its fastenings 65
33. Method of driving chute room in Roslyn field 65
34. Detail of concrete stopping and crosscuts between entries 67

COAL-MINING PROBLEMS IN THE STATE OF WASHINGTON.

By GEORGE WATKIN EVANS.

INTRODUCTION.

The United States Geological Survey has estimated[1] that the State of Washington contains 11,412,000,000 tons of bituminous coal and 52,442,000,000 tons of subbituminous coal, in beds more than 14 inches thick. As the present rate of production is about 4,000,000 tons a year, Washington apparently contains coal enough to supply Pacific coast markets for many years.

The character of the coal beds of Washington renders the production of clean coal very difficult, and a considerable proportion of the output is washed before it is marketed. In 1915 Washington ranked fifth among the States in the amount of coal washed, though only twentieth in total output. In that year 37.9 per cent of the coal produced in the State was treated in surface cleaning plants.

On account of extensive folding and faulting of the coal measures, mining in Washington presents many difficulties; therefore a description of the methods employed at some of the mines may be useful in planning operations in other regions, and is presented in this bulletin.

The coals of Washington differ in quality, ranging from true lignites in Cowlitz County in the southern part of the State to anthracites in the Mount Baker district of Whatcom County, in the northern part. Most of the output consists of subbituminous and bituminous coals, the latter including both coking and noncoking varieties.

Analyses of the coals of the State and descriptions of the beds from which the samples were taken have been printed in publications of the United States Bureau of Mines.[2] Details of coal beds and analyses of the coals of King, Kittitas, and Pierce Counties have also been published by the Washington Geological Survey;[3] and most of the coal beds of the State are described in some detail in a bulletin of the United States Geological Survey.[4]

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[1] Campbell, M. R., and others, The coal fields of the United States: U. S. Geol. Survey, Prof. Paper 100 A, 1917, 96 pp.

[2] Lord, N. W., and others, Analysis of Coals in the United States with descriptions of mine and field samples collected between July 1, 1904, and June 30, 1910: Bull. 22, Bureau of Mines, 1912, Part 1, pp. 201–222, Part 2, pp. 833–906; Fieldner, A. C., and others, Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913: Bull. 85, Bureau of Mines, 1914, pp. 107–110, and 336–344. See also Bull. 123, pp. 115 and 395–397.

In 1918 mining was in progress at 72 mines in the State[4a]; 46 of these mines each employed more than 10 men underground. These mines were distributed as follows: Thurston County, 1; Lewis County, 7; Kittitas County, 14; King County, 16; Pierce County, 6; Skagit County, 1; and Whatcom County, 1. During that year a total of 5,847 men were employed, 4,172 underground and 1,675 on the surface. The average number of days worked in the State was 275, and the average yearly output per man was 706 tons.

Coke is made only in Pierce County by four companies, which have a total of 341 beehive ovens. In 1918 they produced 93,699 tons of coke.

Up to 1919 mining machines were little used in the State. In 1917 only 6.61 per cent of the coal produced was undercut by machines. In that year 58.95 per cent of the coal was mined by hand, and 34.44 per cent was shot off the solid. The explosives used were as follows: Black powder, 36.6 per cent; dynamite, 38.1 per cent; and permissible, 25.3 per cent.

The State of Washington is divided naturally into two parts by the Cascade Mountains which extend north and south somewhat west of the middle of the State. The coal areas east of the range will hereafter be referred to as eastern Washington—though nearly all of it is west of the middle of the State—and that on the west side as western Washington. The geographical distribution of the coal fields is shown in Plate I.

Exploration of the State has not been exhaustive enough to preclude the possibility of discovering, besides the foregoing, other districts that contain deposits of coal in commercial quantities.

ACKNOWLEDGMENTS.

The writer acknowledges with pleasure the assistance rendered by superintendents, mining engineers, managers, foremen, and fire bosses of all the coal companies in the State, who furnished data and maps. The author drew freely also from the excellent reports and suggestions of the State mine inspector, Mr. James Bagley,

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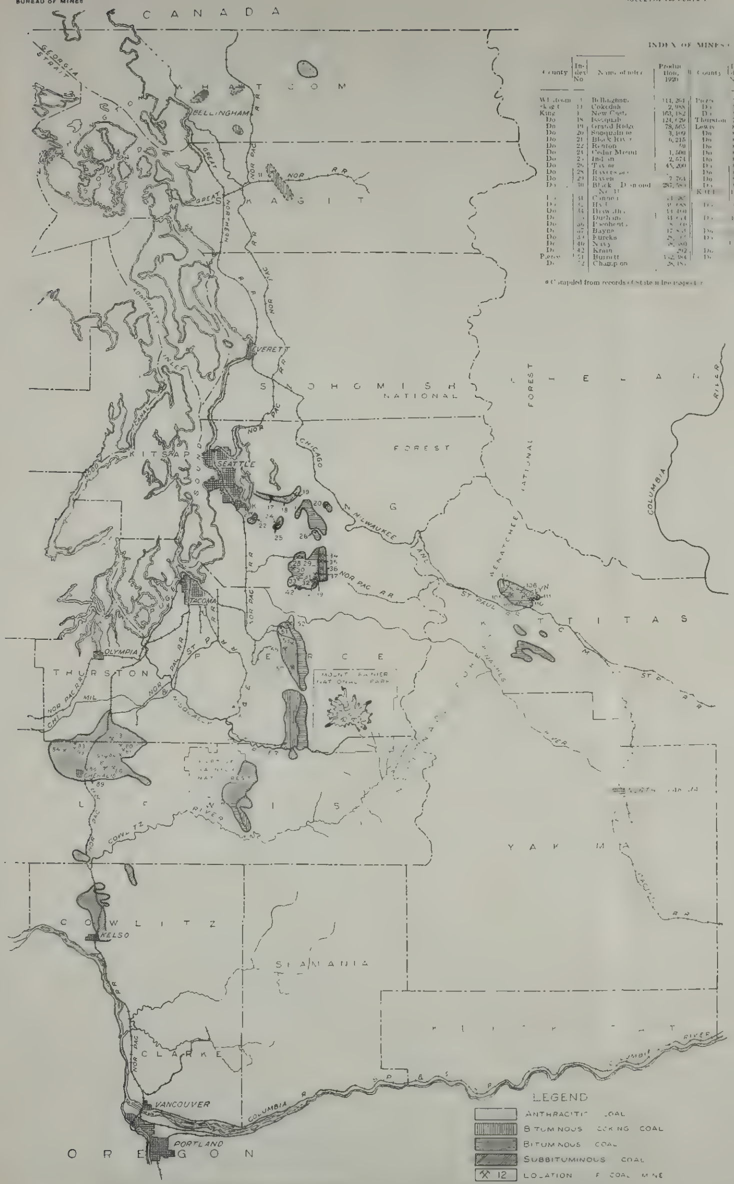
[3] Saunders, E. J., The coal fields of Kittitas County: Washington Geol. Survey Bull. 9, 1914, 204 pp. Evans, G. W., The coal fields of King County: Washington Geol. Survey Bull. 3, 1912, 247 pp. Daniels, Joseph, The coal fields of Pierce County: Washington Geol. Survey Bull. 10, 1914, 131 pp.

[4] Smith E. E., Coals of the State of Washington: U. S. Geol. Survey Bull. 474, 1911, 206 pp.

[4a] The data for this bulletin were collected during the years 1916–1917 and 1918. Since 1918 there have been several changes in the operators of some of the districts of the State.



SKETCH MAP OF WESTERN WASHINGTON, SHOWING COAL AREAS, PRINCIPAL CITIES, AND LINES OF TRANSPORTATION

INDEX OF MINES[a]

County	Index No.	Name of mine	Production, 1920	County	Index No.	Name of mine	Production, 1920
Whatcom	1	Bellingham	114,264	Pierce	[illegible]	Wilkeson	29,7[illegible]
Skagit	11	Cokedale	2,998	Do	[illegible]	Carbonado	[illegible]
King	3	New Castle	163,182	Do	57	Fairfax	[illegible]
Do	18	Issaquah	124,620	Thurston	73	Tono No. 1	[illegible]
Do	19	Grand Ridge	78,565	Lewis	80	Victory	[illegible]
Do	20	Snoqualmie	3,409	Do	81	[illegible]	[illegible]
Do	21	Black River	6,215	Do	82	Mendota	[illegible]
Do	22	Renton	59	Do	[illegible]	Fords Prairie	15,356
Do	24	Cedar Mount	1,500	Do	84	Lincoln	[illegible]
Do	25	Indian	2,674	Do	86	Monarch	[illegible]
Do	26	Taylor	45,200	Do	88	Superior	[illegible]
Do	28	Ravensdale		Do	89	[illegible]	1,140
Do	29	Raven	7,764	Do	92	Silver Valley	1,928
Do	30	Black Diamond No. 11	287,5[illegible]	Do	93	[illegible]	300
Do	31	Cannon	[illegible]	Kittitas	[illegible]	Roslyn Fuel Nos. 1, 2	[illegible]
Do	[illegible]	Hyde	[illegible]	Do	[illegible]	[illegible] Nos. 1, 2	[illegible]
Do	34	Hiawatha	[illegible]	Do	[illegible]	N. W. I. Nos. [illegible]	[illegible]
Do	[illegible]	Durham	[illegible]	Do	[illegible]	N. W. I. Nos. [illegible]	[illegible]
Do	36	Pocahontas	[illegible]	Do	[illegible]	N. W. I. Nos. 7, [illegible]	[illegible]
Do	[illegible]	Bayne	[illegible]	Do	[illegible]	Queen	[illegible]
Do	[illegible]	Eureka	[illegible]	Do	[illegible]	Cle Elum Coal Co.	[illegible]
Do	40	Navy	[illegible]				
Do	42	Krain	202				
Pierce	51	Burnett	[illegible]				
Do	[illegible]	Champion	[illegible]				

[a] Compiled from records of State mine inspector.

and his predecessor, Mr. David C. Botting, in preparing tables and in checking his own observations. Messrs. George S. Rice, chief mining engineer of the United States Bureau of Mines, and Ray W. Smith, chief mining engineer, Pacific Coast Coal Co., assisted in the preparation of this bulletin; and Mr. F. K. Ovitz, a former superintendent of the Seattle station of the bureau, made valuable suggestions. References to bulletins of the Washington Geological Survey have been acknowledged in the text.

GENERAL STATEMENT.

Natural conditions differ widely in the several districts of Washington. Hence the discussion of mining methods does not follow geographical position, but physical conditions; the districts in which natural conditions are simplest are discussed first, and the other districts are considered in the order of their complexity.

WESTERN WASHINGTON.

THURSTON, LEWIS, AND COWLITZ COUNTIES.

SUBBITUMINOUS COAL AREAS.

The subbituminous coal areas of Thurston and Lewis Counties may be considered parts of a continuous field. Figure 1 shows the areas; the mines are listed below.

No.	Name of mine.	Name of company.
1	Tono	Washington Union Coal Co.
2	Packwood	Olympia Coal Mining Co.
3	Fords Prairie	Fords Prairie Coal Co.
4	Mendota	Mendota Coal & Coke Co.
5	Empress	Centralia Coal Mining Co.
6	Kopiah	
7	Monarch	Agnew Fuel Co.
8	Superior No. 2	Superior Coal Co.
9	Sheldon	Sheldon Coal Co.
10	Salzer Valley	Salzer Valley Coal Co.
11	Ladd	Phoenix Coal Co.

TOPOGRAPHY.

The subbituminous coals occur within a series of sandstones and shales which, being easily eroded, have been carved into rounded hills giving a topography more or less like that of a plateau traversed by streams. The elevations range from 192 feet above sea level along the Chehalis Valley to 700 feet near the eastern margin of the coal areas. To the east are mountains largely made up of older sedimentary rocks and igneous rocks, which in places attain an elevation of 2,000 to 2,700 feet.

The topography of the coal district offers little obstacle to railroad building.

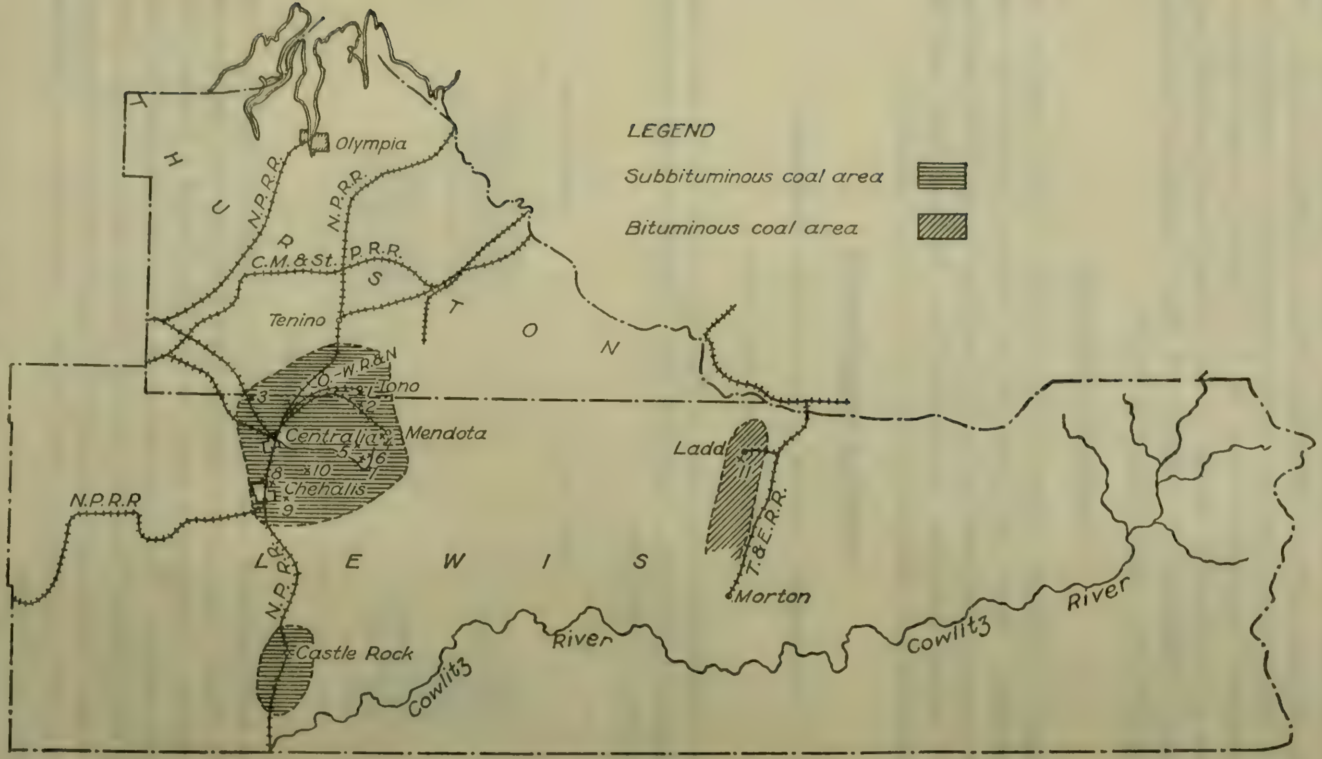


FIGURE 1.—Outline map of Thurston and Lewis Counties showing position of coal areas, situation of mines, and lines of transportation. Names of mines are listed on page 3.

GEOLOGIC STRUCTURE.

For the greater part, the structure of this field is much more simple than that of the King and Pierce County fields. Little or no sharp folding occurs within the areas where coal mines are now being operated, but the beds dip at gentle angles varying from 2° or 4° to 15° or 20°, and in rare instances to 60°. Some faults occur, all normal as far as observed, with such small displacement that there has been little difficulty in finding a bed beyond a fault.

STRATIGRAPHY.

Little effort, if any, has been made to determine the number of beds within these areas or the relations between the beds that outcrop at different places. Drilling at Tono has revealed seven beds within that part of the field. The uppermost bed, known as No. 1, is 17 to 18 feet between walls; No. 2, 50 feet below No. 1, is reported to contain 6 feet of coal and bone; No. 3 bed, 200 feet below No. 2, contains 5 to 13 feet of material; No. 4, 90 feet below No. 3, ranges from 9 to 12 feet between walls; No. 5, 340 feet below No. 4, is from 30 to 36 feet thick; No. 6, 30 feet below No. 5, is reported to have 1 foot 6 inches of coal; and No. 7, 40 feet below No. 6, is 9 feet thick. The relationship between the coal beds at Tono and those mined at Packwood, Mendota, Kopia, Empress, Sulzer Valley, Superior, and Fords Prairie is not yet known, but it is reasonable to suppose that the beds are connected and that the field contains a large tonnage of coal.

CHARACTER OF THE COALS.

The coals are high in moisture and therefore low in heat value, but many of them are comparatively low in ash. Most of the coal is consumed by railroads and power plants for making steam; it is also used for the domestic trade. The Oregon-Washington Railway, as a result of alteration in locomotive fire boxes, is able to consume a large quantity of the coals. The coals are easily mined and will probably be produced extensively at some time in the future.

MINING METHODS AT THE TONO MINE.

As only one important mine is working in Thurston County, only one method of operation is described. Tono mine is at Tono, a coal-mining town on a branch of the Oregon-Washington Railway, 7½ miles northeast of Centralia, in secs. 20 and 21, T. 15 N., R. 1 W.

GEOLOGY AND TOPOGRAPHY OF DISTRICT.

The No. 1 bed, on which the present mine is opened, ranges from 17 to 18 feet in thickness. The upper 5 or 6 feet of coal is bony in places and is commonly left as a roof to protect the main roof. This top coal is sometimes recovered. The roof of the mine is a massive sandstone, which falls when unproteected by the top coal, the caves often extending to the surface. The floor of the bed is a loosely consolidated sandstone, which does not present any difficulties in mining.

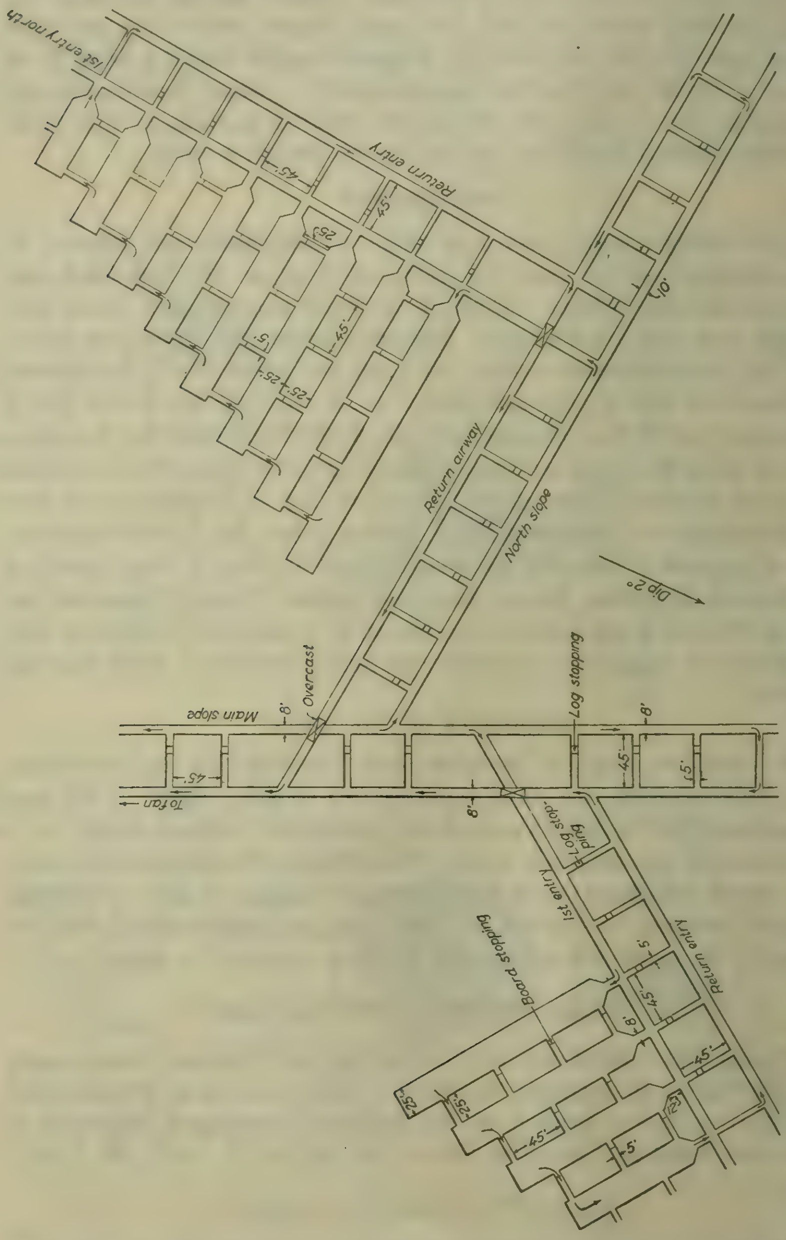


FIGURE 2.—Plan of Tono mine, working a 17-foot subbituminous bed, average dip, 2°, with sandstone walls. Amount of explosive gas, negligible.

The bed dips about 2° toward the southeast. Three faults were encountered in the slope.

The surface in this part of Thurston County is comparatively flat, and as a result little coal is found above water level. Consequently it was necessary to sink slopes, even in the early days of coal mining in this field.

SLOPES AND ROOMS.

In the Tono mine a main slope, 3,000 feet long, with a parallel return airway, has been driven nearly on the dip. The entries are driven on sights and are 8 feet wide. They are separated by a 45-foot pillar through which break-throughs or crosscuts are driven on 45-foot centers. The main slope has a nearly uniform grade, to attain which it was necessary to drive part of the slope in rock, especially in passing through the faulted parts of the bed.

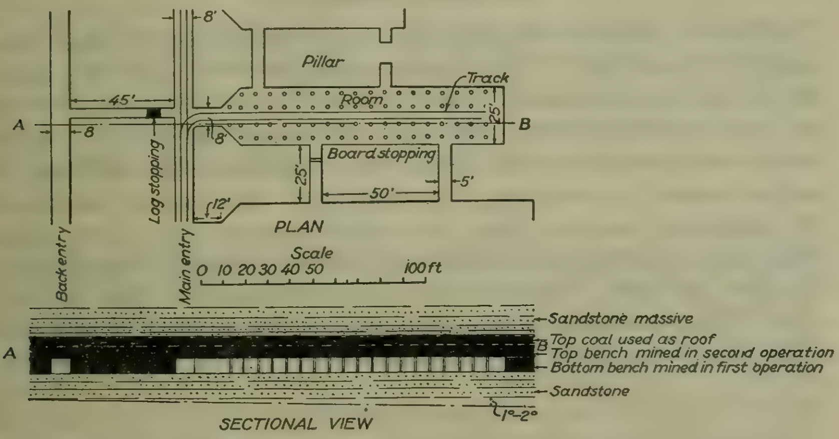


FIGURE 3.—Details of room and entry in Tono mine.

At intervals varying from 300 to 600 feet subordinate slopes or slants are driven, and from them room entries are driven at such intervals as to divide the area into blocks or panels approximately 700 to 800 feet wide.

Rooms are turned from the rise side of the room entries on 50-foot centers and are driven on sights. The necks of rooms are made 8 feet wide for the first 12 feet, beyond which the rooms are widened to 25 feet. On 50-foot centers 5-foot break-throughs are driven between rooms, these break-throughs being alternated so that there is a break-through every 25 feet on one side or the other of each room. This method of operation is illustrated in Figure 2. The track is placed in the center of the room and the top is supported by four rows of props, as shown in Figure 3. The rooms are driven in the lower 6½ feet of the bed, leaving a top bench for a second working.

During the extraction of the pillar coal this top bench is removed. Only enough rooms are turned off to supply the regular demand; when increased production is desired some pillars are drawn.

PILLAR DRAWING.

After the faces of the rooms have reached the boundary of the panel, the pillars are drawn in a retreating direction and the top coal is removed simultaneously to a height of 11 feet, necessitating the use of 11-foot props. The remaining 6 feet of coal above the top bench is sometimes removed, but no special effort is made to recover this part of the bed. Of the coal produced, 43 per cent is obtained in the first mining, and 57 per cent during pillar drawing. It has been estimated, though perhaps not accurately, that the total recovery of coal is 75 per cent.

BLASTING METHODS.

All coal is shot off the solid, each miner attempting to shoot one round of holes a day. This round consists of five holes 6 feet deep and 2½ inches in diameter. Black powder is used, FF and FFF in size, and shots are fired with fuse. Shooting begins 15 minutes before the miners leave the mine. It is estimated that 50 tons of coal are mined for every keg of powder used. Each miner may have 12½ pounds of powder, which is carried into the mine in tin cans. Stemming is sent into the mines from outside. Copper-tipped tamping bars are used. There is no record of blown-out shots at this mine. The shooting is apparently rather severe, as about 80 per cent of the coal passes through a 6-inch screen and is used for locomotives.

HAULAGE AND HOISTING.

Underground hauling is done by a gasoline locomotive on the main haulageways which are used as return airways, and by mules for gathering cars. Thirty-pound rails are used on the main entries and 16-pound rails on the side entries. The track gage is 30 inches. Cars weigh 1,350 pounds and have a capacity of 3,800 pounds. The hoisting on the main slope is done by steam, furnished by two boilers of 300 horsepower.

VENTILATION.

No methane has been detected in the mine, hence a strong air current is not required. The mine is ventilated by a slow-speed fan driven by steam. The quantity of intake air, which is divided into five separate splits, is approximately 56,000 cubic feet a minute. The main slope is the intake and, as the air is split for each panel, overcasts are necessary, as shown in Figure 2. Open lamps, mostly carbide lamps, are used throughout the mine.

TIMBERING.

Little or no timbering is used in driving slopes or on the main or back entries. The props in the rooms are of fir and cedar, set on 6-foot centers. About 2 tons of coal are mined for each prop used. Wooden blocks or logs are used as stoppings in main entries, and board stoppings are used in side entries.

DRAINAGE.

The mine is rather wet, and two electric pumps are used. One is a reciprocating pump, 7 by 8 inches, with a capacity of 250 gallons a minute, and the other a centrifugal pump with a capacity of 400 gallons a minute against a head of 70 feet. Current for pumping is taken into the mine at 2,300 volts, reduced to 440 volts, and again reduced at the pumps to 220 volts.

Because of the dampness little trouble arises from dust, but there have been several instances of spontaneous combustion. To provide for sprinkling when necessary and for extinguishing fires 1¼-inch water lines have been installed with valves approximately 100 feet apart. As substantial pillars are left and rooms are driven on sights, it is possible to seal off fires without difficulty.

PREPARATION OF COAL.

The only preparation given the coal is screening over a 6-inch bar screen 13 feet long. The screenings are used for locomotive fuel on the Oregon-Washington Railway, where its adoption was made possible by special fire boxes. Nearly all of the coal is used by the railroad, but a small quantity of lump coal is used for domestic purposes in the area served by the railroad. Some lump coal is loaded into box cars by a box-car loader.

BITUMINOUS COAL AREA.

Near the central part of Lewis County and a little west of the southern limit of the Pierce County field is an area of bituminous coal that has been opened, and one mine is being operated at Ladd. Another small mine has been started at a place named Watkins or Divide. The coals of this area dip from 30° to 50° and are much faulted. At Ladd the coal-bearing formation seems to be more or less associated with lava flows in the form of sills. Not enough work has been done to determine the total number of coal beds. The following beds have been observed at Ladd: No. 1, 4 feet thick; No. 3, 14 to 15 feet thick; and No. 4, 45 feet of coal, bone, and shale between walls. All of these coals have bands of impurities.

This part of Lewis County is very rugged; therefore railroad transportation will be confined to the valleys. The coal of this district is used for general domestic and steaming purposes. As far as determined, it is not a coking coal nor suitable for blacksmithing. The Ladd and East Creek mines produce bituminous coal, but the output of all others is subbituminous.

The coal fields of Lewis County have not been investigated enough to make possible a definite statement as to the amount of coal they contain, but undoubtedly the subbituminous coal will be adequate to supply a demand larger than the present for many years. There is probably also enough bituminous coal in the East Creek district to last for a considerable time at a greater production than the present.

The present custom of opening a number of small mines and operating them intermittently might well be changed, and larger mines developed and operated continuously. Under existing conditions large quantities of pillar coal are lost through squeezes, and the investment per ton of annual output is larger than it would be under conditions of more steady operation.

MINING METHODS IN LEWIS COUNTY.

OPENINGS.

Because of the flat topography in the coal fields of the western part of Lewis County, it is necessary to sink shafts to reach the coal. In the Ladd district, in the central part of the county, a considerable amount of coal lies above drainage level. As the beds dip rather steeply in most places it is customary to open a mine by sinking a slope in the bed. In one place a slope was sunk through the overlying strata in order to bring the coal to the surface at a point convenient for shipment. In the Empress mine of the Centralia Coal Mining Co. the dip of the bed is only about 5° and the coal is reached by a vertical shaft. In the Ladd mine the opening is a tunnel driven through rock. The slopes are sunk, wherever practicable, on the full dip of the bed, with an airway parallel to the slope and separated from it by a pillar, the width of which varies from 20 to 40 feet. This pillar is pierced by crosscuts every 50 or 60 feet. Only one airway is usually sunk, and in nearly all cases the slope is the intake.

Six mines in Lewis County were examined in detail. Various mining methods were in operation, as the dip varies between 52° at the Superior mine and 3° to 5° at the Mendota. At the mines in which the coal lies most nearly horizontal, room and pillar systems are used; at those in which the coal dips most steeply, chutes are used.

RELATION OF DIP TO SYSTEM OF MINING.

The dip of the coal determines whether cars can be taken to the faces of rooms driven up the dip, whether they can be handled on a plane driven up the dip, from which they are dropped into and hauled out from rooms driven on the strike, or whether the coal will slide downward from the working face to a gangway driven on the strike.

At mines in which the beds dip less than about 10°, it has proved most practicable to drive entries or gangways turned from the slope along the strike of the bed, with a grade of about 1 per cent in favor of the loads, and to turn the rooms from these up the pitch. Empty cars can be pushed to the face of the room. When the dip is too great for convenient pushing, the rooms are turned at an angle to the dip.

At mines in which the bed dips more than 10° but less than 30°, entries are turned up the pitch from the gangways, and from these, rooms are turned on the strike. These openings are known as planes. The empty cars are hauled up by wire rope, and the loaded cars controlled in their descent by the same means. The engines are not located at the top of the planes but at the foot. In beds dipping more than 30°, the coal slides down chutes to the gangways where it is loaded into the mine cars.

EFFECTS OF INCLOSING STRATA.

The strata inclosing the coal beds of Lewis County are so poorly consolidated that they will not stand over large areas without an unusually large amount of timber, and even then they can be held only temporarily. In many places it is impracticable to hold the sandstone roof with timbers, and a layer of coal must be left as a support for the roof, resulting in the loss of much coal. This layer in some places is only 1 foot thick, in other places it is much thicker.

DETAILS OF ROOM AND PILLAR SYSTEMS.

In the room and pillar systems gangways are turned off the main slope at intervals of 300 or 400 feet and are driven along the strike on a grade of about 1 per cent in favor of the loaded cars. An airway parallels the gangway at a distance of 20 to 40 feet, with crosscuts or chutes every 60 feet. In flatter seams the airway has commonly been driven on the lower side of the gangway, but the present tendency is to drive it on the upper side. Rooms, usually 20 feet wide, are driven on 50 to 60 foot centers, with crosscuts between rooms every 50 or 60 feet.

This plan of mining, of course, assumes that pillar coal is to be withdrawn, but no well-established method of pillar work is followed. Where pillars have been drawn the work has usually been begun at the inby end and has been carried toward the gangway.

Figure 4 illustrates the room and pillar method as applied to a mine of gentle dip. The upper part of the sketch shows the older method of working without sights; pillars were not drawn, and more than half of the coal was left in the ground. The lower part of the sketch illustrates the modern method of operation, in which entries and rooms are driven on sights. This latter method, if the dimensions are properly chosen, prevents squeezes and permits the recovery of large quantities of pillar coal.

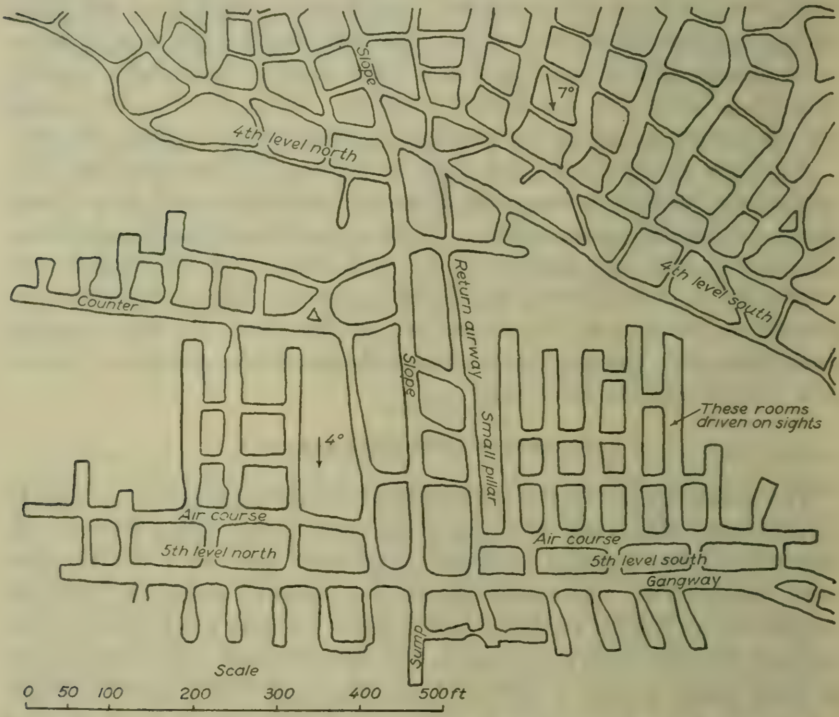


FIGURE 4.—Room and pillar method employed in a Lewis County mine in which the dip is 3 to 5°, the bed 10 feet thick, and the roof and floor are sandstone.

Plane system.—The plane system, though a room and pillar method, is so designated because the cars are handled mechanically on a plane. Planes are driven about 400 feet up the pitch from the gangway. The common width of planes is 8 feet. From the plane, rooms are turned off on both sides at intervals of 37 feet. The room necks are 8 feet wide for a length of 40 feet, and are then gradually widened to the room width of 12 feet. The rooms are from 250 to 300 feet long, and are connected by crosscuts every 60 feet. The pillars are about 25 feet wide and are withdrawn when a pair of rooms have been driven to the boundary, beginning at the inby end.

Chute and pillar system.—The chute and pillar system is used where the coal dips enough to cause the broken material to slide down from the working face to the gangway. Development in the chute system consists of the slope, the gangways, and the chutes. The slopes are similar to those in other systems. The gangways are usually 8 feet wide and are driven along the strike of the bed on a grade of 1 per cent in favor of the loaded cars. A counter or return airway is 30 or 40 feet up the pitch from the gangway. Crosscuts connect the gangway with the airway every 50 or 60 feet. The chutes are generally driven 6 or 7 feet wide between the gangway and the end of the first counter, and above that about 5 feet wide. The soft roof of this mine necessitates the use of narrow chutes. One side of the chute is used as a manway, the other as a coal chute. Crosscuts are driven between chutes every 40 or 50 feet. (See Fig. 5.)

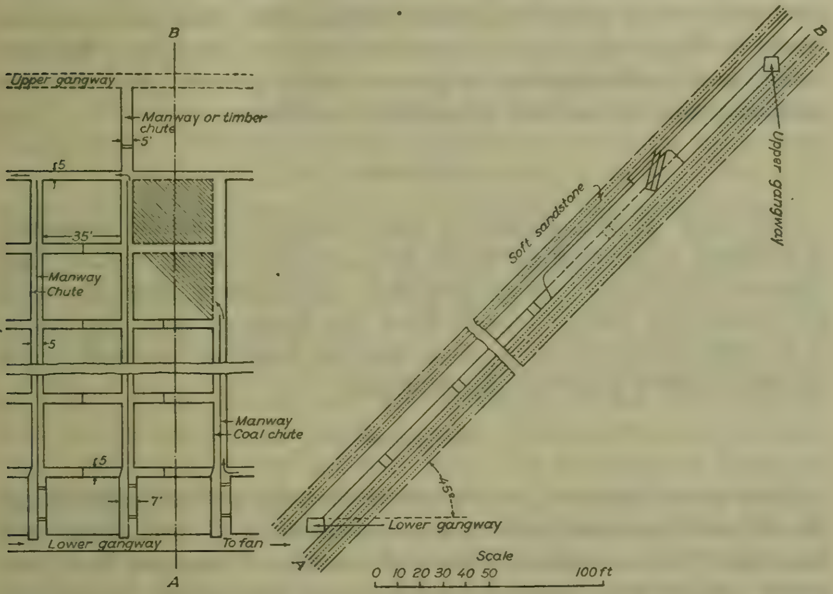


FIGURE 5.—Method of working a 11-foot bed dipping 45°, top and bottom sandstone, chutes driven up in lower bench.

Chutes are frequently driven in the lower 5 feet of the bed until the barrier pillar, separating this block from the gangway of the block above, is reached. At this point, the pillar coal is removed and the whole thickness of the bed, except a bench of top coal which is left to support the sandstone or shale roof, is taken out. At the same time the upper bench of coal is removed within the chute. Half of the coal from a pillar is delivered through the chute on each side. The roof in this district falls so easily that caving frequently occurs before the entire length of the pillar is removed. In order to protect the miners and to prevent the impurities of the caved district from mixing with the coal being mined, batteries of well-lagged posts are left near the top of the coal being worked. Removal of pillar coal is continued until the block above the first counter is reached; this block is usually left to protect the air course.

BLASTING.

Little undercutting is done. In 1917, 72.87 per cent of the coal produced in this county was shot off the solid, 23.10 per cent was mined by hand, and 4.12 per cent was mined by machine. The distribution of explosives was 81 per cent black powder, 18.3 per cent dynamite, and 0.7 per cent permissible explosives.

VENTILATION.

The mines of this district do not produce appreciable quantities of methane and, being generally damp, produce little dust, so that adequate ventilation is easily obtained. The slope is generally made the intake, and the air travels along the gangway from the intake to the last chute or crosscut, then along the working face back to the air course which parallels the gangway.

MINE FIRES.

Fires occur frequently in the mines that are not naturally damp. In one mine especially where the coal is about 11 feet thick, such fires have been a constant source of trouble. Observers have suggested that unusual natural conditions are responsible, but careful examination fails to support their opinion. Pillars are sometimes badly crushed and, as a result, spontaneous combustion might easily occur; temperatures observed in the mine ranged from 62° in one part to 95° in another. On account of the likelihood of fires in this district, openings should be driven on sights and pillars should be left wide enough to stand without danger of crushing. Thus the crushing of pillar coal, which exposes large surfaces to the oxidizing action of the atmosphere, will be prevented. A pillar not less than 100 feet wide should be left between the main slope and the return airway, and no room should be turned off the gangway at a distance less than 150 feet from the slope or airway unless absolutely necessary. Adequate pillars being left, fires should be largely prevented; if fires should occur it would be easy to seal off the fire area.

PREPARATION OF COAL.

Except in the Ladd district, the coal beds of this area do not contain large quantities of impurities, and generally hand picking of the larger sizes is the only cleaning attempted. At three plants washeries have been installed for treating the smaller sizes, the equipment consisting of a Blair jig at one plant, a Forester jig at another, and a tub washer at the third.

WHATCOM AND SKAGIT COUNTIES.

The existence of anthracite on the northwest slope of Mount Baker has been known for 25 or 30 years. About a quarter of a century ago a coal company spent large sums in prospecting unsuccessfully for commercially valuable antharcite on Cornell Creek. Good specimens of coal have been found, and some fairly large lenses have been exploited. In the Blue Canyon area, on the east shore of Lake Whatcom, the Blue Canyon mine has been operated for more than a quarter of a century, but is at present nearly exhausted. The output is a high-grade bituminous coal, having gas-making properties.

The coal beds or lenses of this district occur near the contact between the underlying schists and the later sedimentaries. The extent of the coal is unknown, but it seems reasonable to think that other lenses will be discovered. The coal area north of Sedro-Wooley on the Skagit River—locally known as the Cokedale district—is undoubtedly the southern extension of the Blue Canyon field, and the coal is of the same character as that in the Blue Canyon mine. Moreover, the coal at both places lies in elongated lenses at the contact between the sedimentaries and the underlying schists. Apparently this field extends into the hills south of the Skagit River. A mine at Cokedale was operated more than 20 years ago, but has been closed for many years. Work was being resumed there at the time of writing.

BELLINGHAM MINE, WHATCOM COUNTY.

While prospecting is being carried on to a considerable extent in Whatcom County, only one mine is being developed on a large scale. Bellingham mine, operated by the Bellingham Coal Mines, is located near the city limits of Bellingham in the SE. ¼ of the SE. ¼ of sec. 13, T. 38 N., R. 2 E., on a branch of the Bellingham & International Railway. A shaft was started in February, 1918, and completed during the year, reaching the coal at 276 feet. In November a slope was started, was driven at an angle of 36°, and reached coal at 600 feet. Beyond the point of intersection with the bed, the slope was continued on the dip and levels were turned off on the strike.

The method of mining contemplated was room and pillar, with rooms 20 feet wide and pillars 30 feet. Since the foregoing was written, the Bellingham mine has been developed to over 1,000 tons per day.

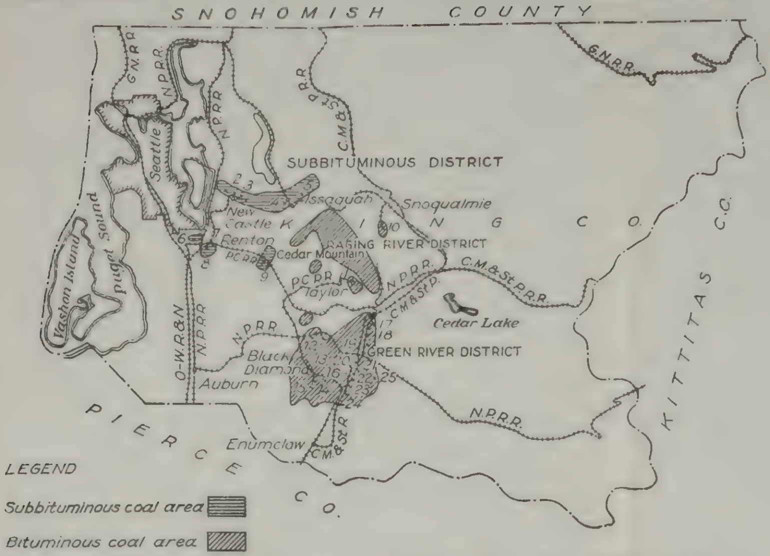
KING COUNTY.

The coals of King County occur in four districts. The subbituminous field is nearest Seattle, the Raging River district lies to the east and southeast of Seattle, the Cedar River district is south of the city and west of the Raging River, and the Green River district is to the south of the Raging River district.

SUBBITUMINOUS DISTRICT.

The subbituminous district is rather disconnected (see Pl. II), as the relationship between the Renton coal and that occurring at New Castle, Issaquah, and Grand Ridge remains unknown. The Renton coal is similar in quality to that in the larger district, thus lending probability to the idea of a connection between the two fields. The relationship between the Renton and the Cedar Mountain coal beds is more definitely established, and probably an area of coal land not yet discovered exists between these two districts. The coal beds being worked at New Castle, Coal Creek, Issaquah, and Grand Ridge are undoubtedly connected. Moreover, a definite correlation of many of the beds can be established throughout the entire length of this field. The May Creek bed at New Castle, for example, is the bed known as No. 5 at Issaquah and as No. 3 at Grand Ridge.

At Renton and Cedar Mountain the topography is comparatively simple, the Cedar River Valley being the predominating feature. On each side of this valley glaciated hills extend to the north and south in the form of plateaus ranging in height from 100 to 500 feet above sea level. These hills are made up largely of glacial clays and gravels, constituting a mantle that has masked the coal measures, except at a few points where Cedar River and its tributaries have exposed underlying formations. The New Castle-Issaquah area is far more rugged than that to the south and, with the exception of the eastern margin of the Green River district and part of the Raging River district, is more rugged than any other part of the coal fields of the county. The coal beds of this area dip to the north and overlie what seems to be a series of lavas and volcanic tuffs that form Squak and Issaquah Mountains. The highest point within the coal area proper is a hill between the headwaters of Coal Creek and Tibbetts Creek; this hill reaches an elevation of 1,500 feet above sea level. Squak and Issaquah Mountains, which have an elevation of nearly 2,000 feet above sea level, are formed of underlying igneous rocks.



Number.	Name of mine	Name of company.	Number	Name of mine.	Name of company
2	New Castle	Pacific Coast Coal Co	14	Cannon	Pacific Coast Coal Co.
3	Ford Slope	Do.	15	Kummer	Denny-Renton Clay & Coal Co
4	Issaquah	Do.	16	Hyde	Hyde Coal Co.
5	Grand Ridge	Central Coal Co	17	Kangley	Twin River Coal Co.
6	Earlington	Black River Coal Co	18	Hiawatha	Northwestern Improvement Co.
7	Denny-Renton	Denny-Renton Clay & Coal Co	19	Durham	Durham Collieries Co.
8	Renton	Renton Coal Co.	20	Occidental	Occidental Coal Co
9	Cedar Mountain	Cedar Mountain Coal Co	21	Bayne	Carbon Coal & Clay Co
10	Snoqualmie		22	Eureka	Eureka Coal Co.
11	Taylor	Denny-Renton Clay & Coal Co	23	Navy	Ozark Coal Mining Co
12	Raven	Raven Coal Co.	24	National	National Coal Co.
13	No. 11 Mine	Pacific Coast Coal Co	25	Pocahontas	Pocahontas Coal & Coke Co

OUTLINE MAP OF KING COUNTY, SHOWING CLASSIFICATION OF SEVERAL COAL DISTRICTS, POSITION OF MINES AND LINES OF TRANSPORTATION.

Within the Renton coal measures there are three coal beds, of which No. 3 has been worked extensively at the Renton mine. There is foundation for the belief that other beds occur beneath No. 3, but only careful drilling can determine the facts. Three beds also exist within the Cedar Mountain measures, two of which, principally the No. 2, have been worked to some extent. It is known that other beds exist below No. 2. At the Coal Creek mine, a detailed cross section of the rock tunnel (see Pl. III) shows nine coal beds and bony beds within this part of the field. Four of these beds have been worked extensively within the New Castle Coal Creek mine. At Issaquah the same series of beds has been opened by means of slopes and rock tunnels and the same coal beds developed that were mined at New Castle, though some of them have changed in character. An equal number of beds has also been exposed by rock tunnels at Grand Ridge, but at this place the No. 4 bed, which produced some of the best coal in the New Castle Issaquah mine, was too low grade to warrant working.

The total thickness of the beds of the New Castle, Coal Creek, Issaquah, and Grand Ridge areas averages 32 feet 6 inches of coal. No satisfactory estimate of the amount of coal existing in this field can be made, as the area lying between the mines has not been prospected enough to reveal the thickness or the character of the beds.

RAGING RIVER DISTRICT.

The Raging River coal area occupies the northeastern slope of the range of mountains that extends in a northwesterly direction from Cedar River and connects with Issaquah Mountain. The district takes its name from Raging River, in the drainage basin of which it lies.

The only mine that has been at all successful is the Snoqualmie, on the east margin of the district, but even this mine has been operated intermittently. The coal in this part of the field produces a fair grade of coke, but mining conditions have been so unfavorable that a profitable mine has not yet been developed.

The mountains along the slope of which the Raging River district lies, seem to be made up largely of a series of lava flows and tuffs, conformable to the coal measures, these being of the same class of material as Issaquah Mountain. The elevations within the field range from 700 feet above sea level along the river, to 2,500 feet above sea level, along the crest of the mountains.

Because of the faulted condition of the strata within this basin it has been impossible to determine definitely the number of coal beds, and no certain connection has yet been made between the beds of this district and those of adjacent districts. Some of the outcrops contain good coal, but on account of difficulties of transportation from the field and the uncertain character of the beds no detailed study of the geology has been completed.

CEDAR RIVER DISTRICT.

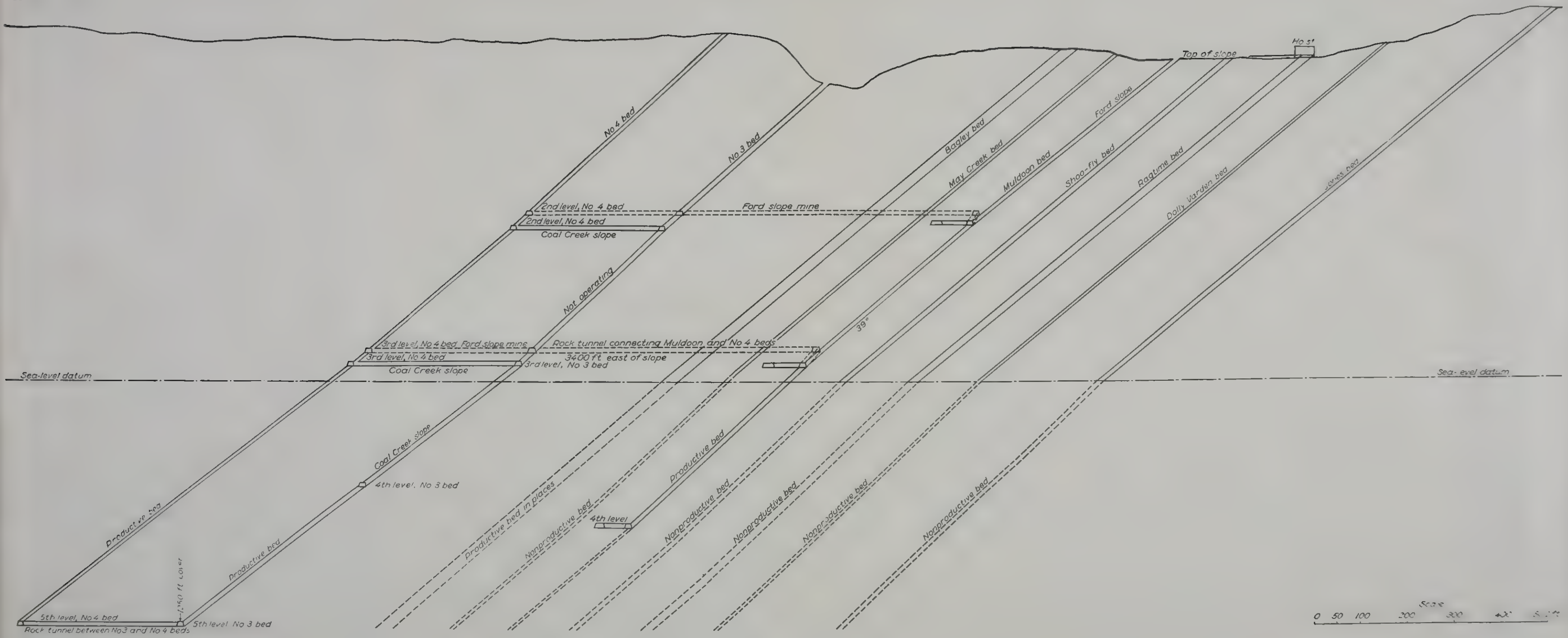
South of the Raging River district is the Cedar River district, a small section less than 2 square miles in area, separated from the other coal areas of King County by underlying igneous material. A correlation between this isolated area and other coal fields has not yet been made. The only mine operated in this district is at Taylor, where a clay company is producing coal for burning its wares and for general use in generating steam in the Puget Sound region. Nine or more coal beds have been discovered at this place and several have been opened. Numerous attempts have been made to develop a mine at Barneston, but have been unsuccessful, as the coal is of uncertain character and many bony beds are found.

GREEN RIVER DISTRICT.

The Green River district—which contains 54 square miles of coal land—lies southeast of Seattle. The 14 mines that have been developed in this section lie 30 to 45 miles from the city by rail. The limits of the district are not definitely known; they may extend to the northwest through Ravensdale and Danville, connecting the field with the Cedar Mountain beds.

The western and central parts of this field consist of a series of gravel plains out of which well-rounded hills rise to elevations of 500 to 800 feet above the general level. Winding in a southwesterly direction through the district, Green River has cut its bed through glacial material into underlying coal formations. This river has precipitous canyons, in many places 300 to 400 feet deep. Along its eastern margin the field rises to the foothills of the Cascade Mountains, which are made up of recent lava flows overlying the coal measures. These mountains rise abruptly from the level of the gravel plains to a height of 3,000 to 4,000 feet. The district is connected by railroad with Seattle and Tacoma, though the eastern margin is still rather inaccessible on account of precipitous foothills.

It is not yet possible to give the stratigraphy of the Green River field in detail, but some general relations can be mentioned. The measured coal-bearing strata represent a total thickness of more than 8,000 feet and have been divided into three series: The Upper, or



STRATIGRAPHIC RELATIONSHIP OF COAL BEDS MINED AT FRANKLIN, KING COUNTY.

Kummer, 1,751 feet thick; below this, an intermediate zone known as the Franklin, 3,620 feet thick; next the Bayne, 3,021 feet thick.[5]

KUMMER SERIES.

At least 10 beds of coal and bony coal have been observed within the Kummer series, 4 of which have been worked at the Kummer mine on Green River, shown as No. 15 in Figure 6. This coal is fair grade, but is higher in moisture and somewhat higher in ash than the better coals in the Franklin series.

FRANKLIN SERIES.

About 20 coal and bony beds have been observed among the coals, sandstones, and shales that constitute the Franklin series. Near the central part of the series is the well-known McKay bed, which ranges in thickness from 4 to 6 feet. The excellent quality of this coal is largely responsible for the early development of the field. Several other beds contain coal of good quality, but higher in ash; among them are the Gem, the Fulton or No. 12, No. 10, and No. 9. These beds have been mined to some extent at Franklin. The Fulton, or No. 12, which is being developed at the Hyde mine, was formerly mined at Franklin and at Black Diamond.

BAYNE SERIES.

The Bayne series, the lowest of the three areas of the Green River field, has been extensively developed. It is difficult, however, to determine the stratigraphy of the beds, as they are sharply folded and considerably faulted where they are most exposed along the Green River canyon. According to the general assumption, the Durham, Occidental, Bayne, and Eureka mines have been opened on beds within this series, but it is not yet known just what relationship exists between these beds and those upon which the Hiawatha, Pocahontas, Navy, and National mines have been opened. The difficulties in correlating the beds are increased by the fact that the coal changes in character within comparatively short distances.

Folding and faulting increase from the western part of the field in the vicinity of Black Diamond and Franklin, where the folds are comparatively open, toward the eastern margin near the Bayne and Pocahontas mines, where the folds are much more compressed. Five synclines and five anticlines have been recognized with axes pitching in a southerly direction. Folding has affected the character of the coal, the moisture content of the McKay coal being higher at the western end of the Black Diamond mine and at Ravensdale than at the Cannon and Hyde mines. Toward the eastern limit of the coal area the coals are lower in moisture.

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[5] Evans, G. W., The coal fields of King County: Washington Geol. Survey, Bull. 3, 1912, pp. 46–49.

BEDS OF THE GREEN RIVER DISTRICT.

The complex folding and faulting render it impossible to determine the number of coal beds in the series. From measurements made by the writer some years ago it was estimated that 23 outcrops of coal and bony beds had been observed, but later observations led to the conclusion that the number is smaller. The beds within this series range in thickness from 3 to 40 feet of coal and bone.

MINES OF THE GREEN RIVER DISTRICT.

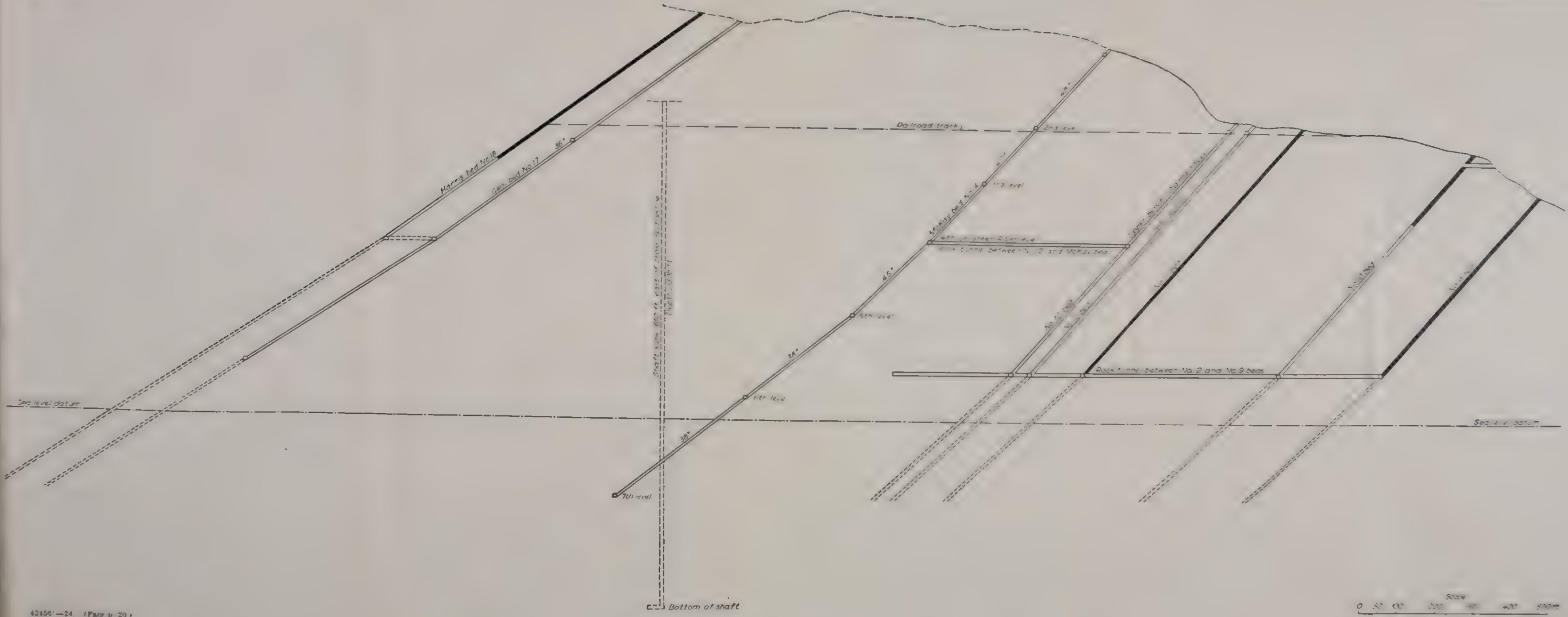
RAVENSDALE MINES.

At the Ravensdale mine, owned by the Northwestern Improvement Co.—a subsidiary of the Northern Pacific Railway Co.—several coal beds occur. No. 9 contains 3 feet 3 inches of coal; No. 5 is from 20 to 30 feet between the walls, and contains an average of 25 feet of coal and bone. Nos. 4, 3½, and 3 beds really constitute one large bed containing about 33 feet of material between walls. Nos. 4 and 3½ beds, parts of this bed, were mined as one, and No. 3 as a separate bed. The actual thickness of coal in these three parts of the bed amounts to about 22 feet of coal and bone, though the coal is not very high grade. Below these beds is No. 2 bed, which contains about 8 feet of coal and bone; next below is No. 1 bed, containing 12 feet of material between walls. Below No. 1 bed lies the Gem, comprising 5½ feet of coal and bone; then at some distance below the Gem is the McKay bed. As observed at one place, the McKay bed consists of two benches, the upper containing 4 feet 2 inches of coal and the lower 4 feet 10 inches of coal, with a parting 2 feet 7 inches thick between them. Other beds also occur within the properties.

BLACK DIAMOND, FRANKLIN, CANNON, HYDE, AND KUMMER MINES.

At the Black Diamond mine the McKay seam has been extensively mined and the Fulton, or No. 12, has been worked slightly.

At Franklin (see Pl. IV) the Gem, McKay, and Nos. 12, 11, and 10 beds have been mined, the most work being done on the McKay bed. Much coal has been taken from the overlying Gem bed and some from the No. 12, or Fulton, bed. The quantity of coal produced from No. 10 and No. 11 beds is negligible.



STRATIGRAPHIC RELATIONSHIP OF COAL BEDS AT FRANKLIN, KING COUNTY.

At the Cannon mine both the Gem and McKay beds are being developed, though more work is done on the McKay seam, which contains at this place 3 feet 8 inches of coal in the lower bench and 2 feet 6 inches in the upper bench. At the Hyde mine the McKay bed is being developed principally, and some work is being done on No. 12. The McKay bed is 9 feet 7 inches between walls and has a lower bench of 4 feet and an upper bench of 2 feet of coal, both being mined. No. 12 bed contains 25 feet of material between walls, but only the lower bench—consisting of 6 feet 6 inches of coal and bone—was being mined at the time of writing. In the Kummer mine, bed No. 0 is 4 feet 11 inches thick, and bed No. 1 is 5 feet 7 inches thick.

KANGLEY, HIAWATHA, DURHAM, OCCIDENTAL, NATIONAL, AND POCAHONTAS MINES.

At Kangley a slope was sunk on the Kangley bed. Several beds were observed at Hiawatha on the surface, such as the Hiawatha, Blacksmith, and Upper and Lower Mammoth. At Durham two beds, apparently underlying those at Hiawatha, have been developed. Of these, No. 1 is over 25 feet thick, the lower 6 feet 5 inches of which is being mined. At the Occidental mine, which was closed when this report was written, a bed with a total thickness of 28 feet was developed. This bed contains a lower bench of coal 5 feet 3 inches thick, and an upper bench of coal and bony coal 11 feet 2 inches thick. At Bayne, No. 1 bed contains 13 feet of coal and bony coal; No. 3 bed, 4 feet 2 inches of coal and bony coal; and No. 5 bed, 11 feet 5 inches of coal and bony coal. The seams opened at the Eureka mine are southern extensions of those worked at Bayne.

The relationship between the beds worked at the Navy and Sunset mines and those worked at the Bayne and Occidental mines, which lie to the north, has not been determined. At the Navy mine the Navy bed is 30 feet from wall to wall and consists of a lower bench of coal and bone 5 feet thick and an upper bench of coal and bony coal 11 feet 1 inch thick. Several other beds within this area contain coal of varying qualities, all high in ash. Only the coals that are lowest in ash are now being mined. At the National mine several beds have been opened, consisting of coal and bone ranging in thickness from 3 feet 3 inches to 35 feet. In general the coal in this part of the field contains a high percentage of ash. At the Pocahontas mine, in the eastern part of the field, much work has been done on two beds. No. 2 bed, with 20 to 25 feet of coal and impurities, contains some coal of very good quality. No. 3 bed, on the same property, is 18 feet thick and, although it has several impurities in the form of shale bands, contains coal of high grade.

KINDS OF COAL.

The discussion of mining methods in King County is somewhat complicated by the fact that two kinds of coal are produced, the subbituminous coal mined at Renton, Coal Creek, Issaquah, and Grand Ridge, and the bituminous coal mined in the other coal areas of the county. The mining methods employed in different parts of the county are similar enough to make possible some general discussion; after it are given details of the different mines. The subbituminous coals are medium grade. Because of their high moisture content and the fact that they are noncoking, they have not proved very successful for use under hand-fired boilers, but they are giving satisfaction in mechanical stokers. These coals are principally used for domestic purposes, but wider use of powdered fuel will enlarge their market. The bituminous coals are high grade. Most of the coal is noncoking, but along the eastern margin of the field coking coal has been mined in two places, and coke ovens were built at the Snoqualmie mine. The bituminous coal from King County is used for domestic purposes and for generating steam.

FORMS OF OPENINGS.

As the surface is not horizontal and the strata are dipping, the coal is found in all positions from high up on the hillsides to deep beneath the surface. It was natural, therefore, that the first openings should be levels driven into the hillsides for the extraction of coal lying above the general water level. After a large part of the hillside coal had been extracted, the sinking of slopes on the coal bed was begun to develop the coal lying below water level. When the beds did not outcrop at convenient places, rock tunnels were driven to reach the coal beds.

Some slopes reached considerable depths. Coal is being mined in one place under a cover of 1,850 feet, and in another under a cover of 1,250 feet. The economic limits of depth have not yet been reached, but increasing depth requires the use of more timber and increases the cost of drainage and hoisting. Along the eastern margin of the field the coal beds dip directly into mountains that rise 1,000 to 3,000 feet above the general level of the district, and the increase in depth of cover is more rapid there than in other parts of the field.

SURFACE TRANSPORTATION.

In the area of subbituminous coal, the surface topography is not rugged enough to present serious obstacles to transportation and there is no difficulty in constructing railroads to mine openings. In the area of bituminous coal the topography is more broken, and several long tramways have been built from the mines to the railroad tracks. These tramways are usually built with a grade of 1 per cent in favor of the loaded car, but at one mine it was necessary to build an incline that was operated partly by gravity.

MINING OPERATIONS IN KING COUNTY.

The beds are opened by levels or rock tunnels or by slopes. From the levels or from gangways driven from the slopes, the coal is extracted up the pitch. Where the dip is so great that cars can not be run into rooms, but not great enough to cause coal to slide in chutes, planes are driven up the pitch and rooms are opened on the strike. Where the bed dips enough to cause the coal to slide, it is extracted by chutes and pillars or by breasts and pillars. The chute serves as an opening through which men reach the working face on one side, and the coal is dropped from the working face to the gangway on the other side. A small proportion only of the coal mined is taken out during the advance. In the breast and pillar workings a higher percentage of coal is taken out on the advance. The distinction between chute and breast is commonly made at 10 feet—that is to say, an opening more than 10 feet wide is a breast, whereas one of less width is a chute. The choice between these two methods is determined largely by the character of the roof.

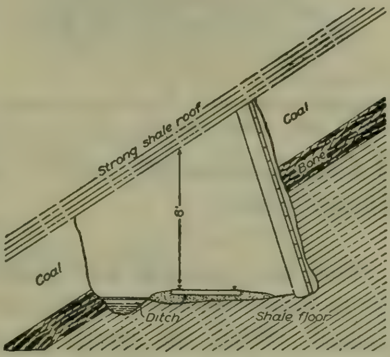


Figure 6.—Method of timbering in gangway; strong roof; dip, 35°.

GANGWAYS.

Gangways and levels are driven in the beds, generally with a grade of about 1 per cent in favor of the load. The form of timbering used depends on the character of the roof. Figure 6 shows the timbering used with a strong roof. A short prop is sometimes used on the lower side of the gangway to keep the coal from sloughing off into the ditch.

The method of timbering used where the roof is weak is shown in Figure 7. The size of the timbers depends on the character of the ground and varies from 10 to 16 or 18 inches in diameter. The lagging is occasionally put in skin to skin, whereas in other places only three or four strips of lagging are placed on the collars and one or two strips on the sides.

The depth of excavation in the floor depends on the dip of the bed and on the kind of car used. It is customary to have the bottom of the chute clear the top of the car by 2 inches, and enough of the bottom is ripped up to accomplish this. In beds dipping less than 50° or 60° the amount of bottom excavated is considerable.

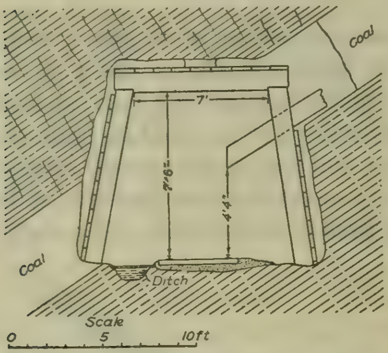


FIGURE 7.—Method of timbering in gangway; weak roof; dip, 35°.

A ditch is excavated on the side of the gangway opposite the loading chute. In some mines this is covered to prevent filling with material spilled from the cars. Some tracks are ballasted with ashes or fine gravel brought in from the surface.

Figure 8 illustrates the use of square timber in a gangway with a roof that is strong, but scales off. This sketch shows also the method of hanging the trolley wire in an inverted trough, and the use of a hinged chute.

TUNNELS.

When the sides and roof stand well, little or no timber is needed, but in shale that disintegrates after exposure to the air, light timber is used. When the tunnel passes through a fault zone or a carbonaceous bed with a tendency to heave, it is sometimes necessary to place timbers skin to skin and to lag with 3 by 12 inch planks, also using mud sills under the legs. Single-track tunnels are generally about 7 feet 6 inches high and 10 feet wide.

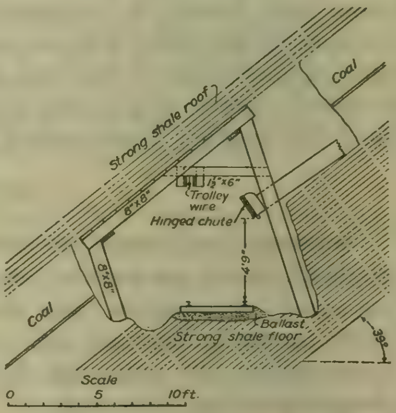


FIGURE 8.—Method of timbering gangway; strong roof which scales off.

SLOPES.

Slopes are sunk on the full dip of the bed up to a dip of 45° and are laid with either single or double track, according to the output anticipated. Figure 9 shows arrangements at the connection between a slope and a level. Turnouts are made either in the coal or in the rock, those illustrated being in the rock. Much greater speed can be obtained by hoisting with the arrangement shown in the figure than when turnouts are made in the coal. With the latter, if trips are started or landed at too great speed, especially in a heavy dip, wrecks frequently occur in spite of the guardrails.

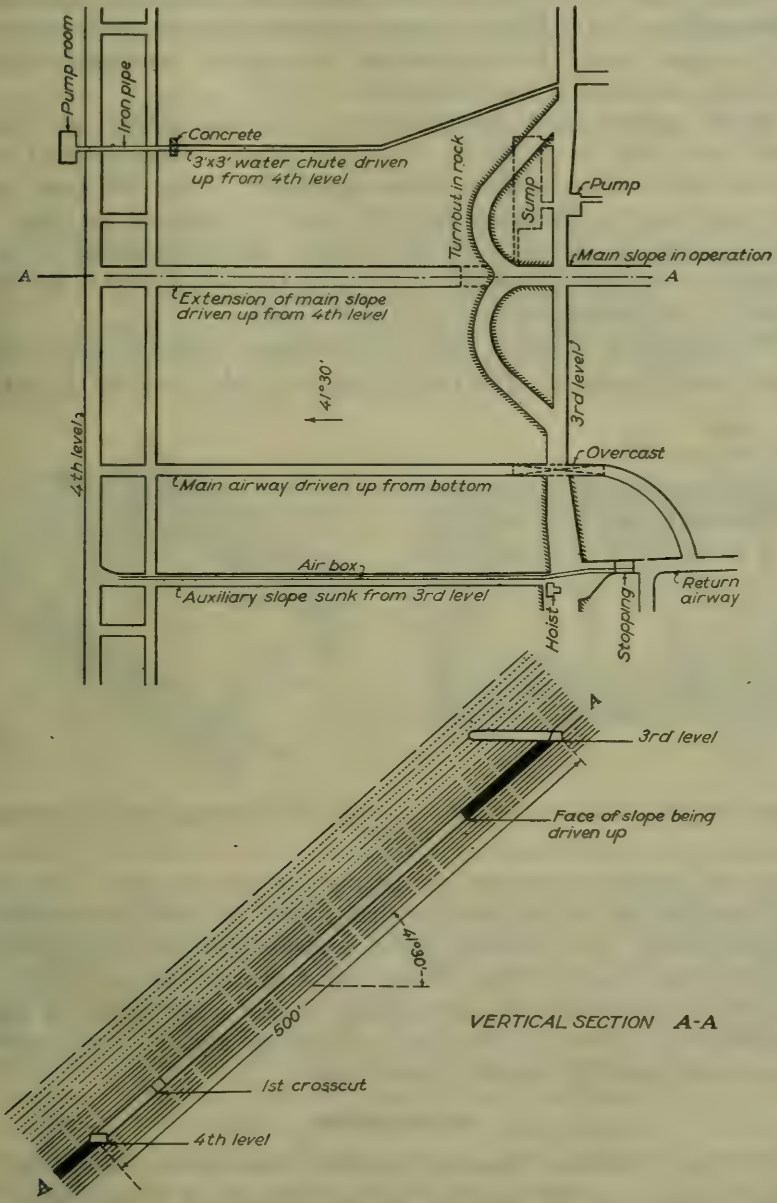


Figure 9.—Method of slope development used in coal bed 5 feet 8 inches thick; dip of 41° 30′; both walls shale.

Figure 9 illustrates also the method of development used by one company, in which an auxiliary slope is sunk from the upper level to the next lower level, and the main slope is driven upward. The material excavated is raised by a hoist in the upper level. At the bottom a gangway and counter are turned off, and at a convenient distance from the auxiliary slope a permanent airway is driven up to the upper level. During sinking, the slope is ventilated by an air box, a rectangular pipe of boards.

At the proper point, determined by a careful survey, the full-sized main slope is driven up from the bottom. The material excavated slides down a chute to the gangway. After the slope has been excavated to the upper level, the track is laid and the slope is put in condition for use. By this method the development is kept in advance of mining and the working of the lower level is not delayed by the necessity of first sinking the slope.

The timbering of one of the best constructed slopes in the county is shown in Figure 10. The roof of the coal bed is used as the main roof, and height is obtained by lifting the bottom rock. The ties and stringers are bound together firmly and the whole construction is substantial. Great hoisting speed is attained in this slope, yet no delays occur from wrecks. Many slopes are not as well built as that illustrated; where too great saving in first cost resulted in poor construction the work of the mine is hampered and the cost of operation is increased by wrecks on the slopes.

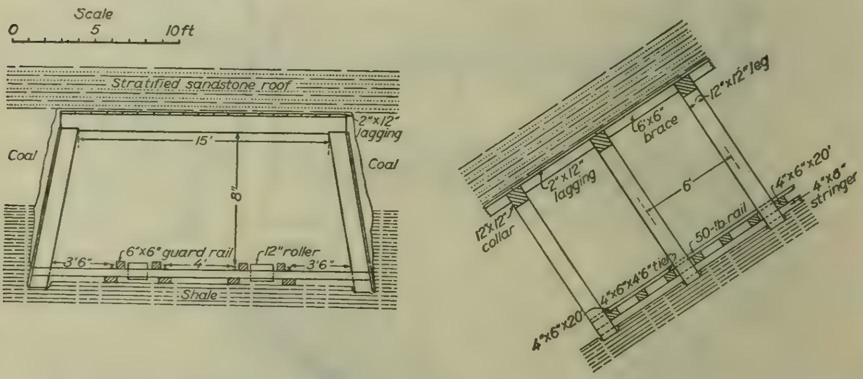


FIGURE 10.—Cross sections of double compartment slope showing method of timbering; dip, 45°.

PLANE SYSTEM.

The plane system of operation has been described in the section on Lewis County (p. 12), and the method followed in King County is practically the same. At the Renton mine planes are turned directly up the pitch at intervals of 200 to 260 feet, the standard distance being 220 feet; at intervals of 50 feet, 17-foot rooms are turned. Rooms are staggered to prevent interference of switches and frogs. The track in the room is kept near the upper rib, and refuse is stowed in the space below it. When pillars are to be drawn the track is turned up the pitch and across the end of the pillar.

At the Carbon mine of the Carbon Coal & Clay Co. a double-track plane was driven up the pitch and 10-foot rooms were turned off on 40 or 50 foot centers. The roof is allowed to cave in the worked-out area. Roof pressure is so regulated that no powder is necessary.

CHUTE AND PILLAR SYSTEM.

Where the roof is poor or the weight of the overlying material so great that it is difficult to prevent caving, the chute and pillar system is used. The common practice is to drive a gangway along the strike of the bed on a grade of about 1 per cent in favor of the loaded cars. Parallel to this is a counter, usually about 30 feet up the pitch. At intervals of 50 to 60 feet, chutes are driven up the pitch from the gangway to the counter, generally in the bottom of the bed. Above the counter the chute is continued up the pitch to the limit of the lift in the chute and pillar system, whereas in the breast and pillar system the working face is widened. After a series of chutes have been driven to their limits the pillars between them are removed and at the same time the top coal is taken down in chutes.

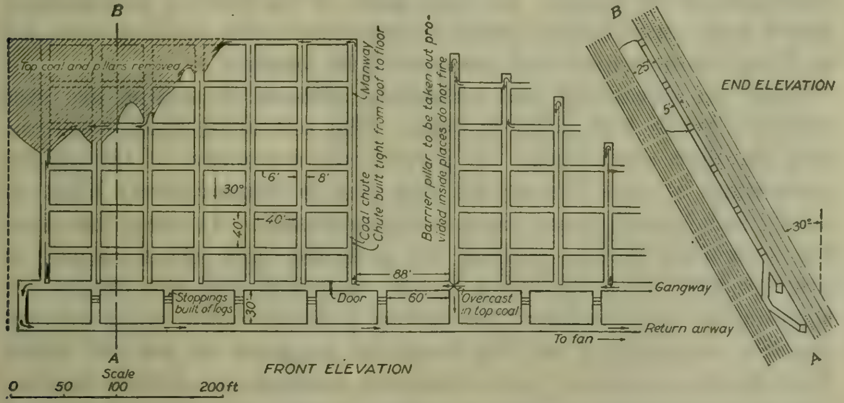


FIGURE 11.—Chute and pillar system of working a 25-foot bed of bituminous coal; dip, 30°.

Figure 11, drawn from the map of the Ravensdale mine, shows one method of working the chute and pillar system. Chutes 8 feet wide are driven on 48-foot centers, thus leaving 40-foot pillars. The counter is driven below the gangway. The bed has the unusual average thickness of 25 feet. The mine is divided into panels consisting of seven chutes, and pillars are left between panels, through which chutes can be driven when the pillars are to be removed. After a group of chutes has been driven to the boundary, withdrawal of pillar coal is begun and the retreating working face is carried practically as shown in Figure 11. Thus the system might be called panel longwall, retreating. This method of operation permits a high percentage of recovery.

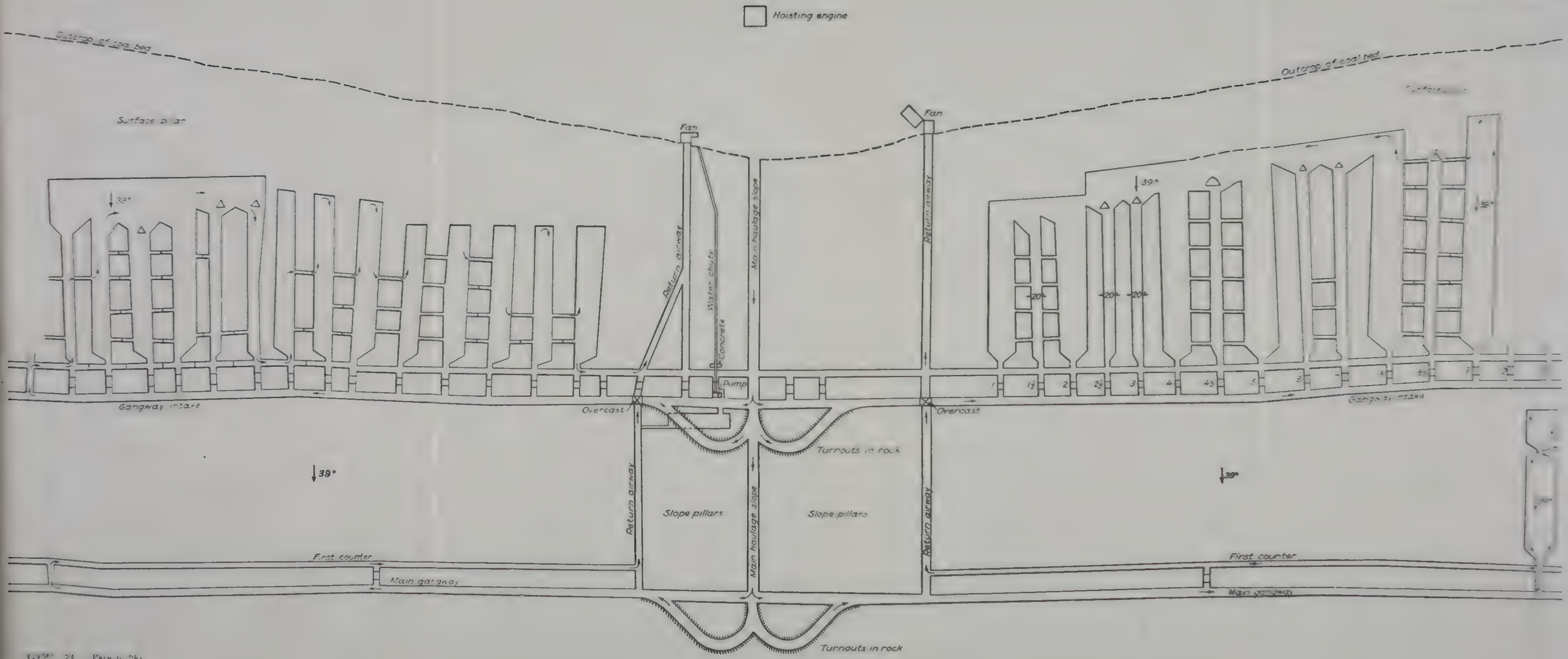
BREAST AND PILLAR SYSTEM.

The conditions that determine the width of breasts are stability of roof and pressure of overburden. Breasts range from 10 to 70 feet in width. When the dip is sufficient to cause the coal to slide, a chute is built in the center of the breast or on the side, depending largely on the width of the breast, and the coal drops down the chute to the gangway. When the dip is too flat for coal to slide, tracks are carried up the breast and small cars are used to carry the coal from the working face to the loading chute on the gangway, pulleys or " McGinties " being used in order that the descending car may pull up the empty. In other parts of the State it is customary under such conditions to take the mine car to the working face, but in King County small cars are used in the breasts.

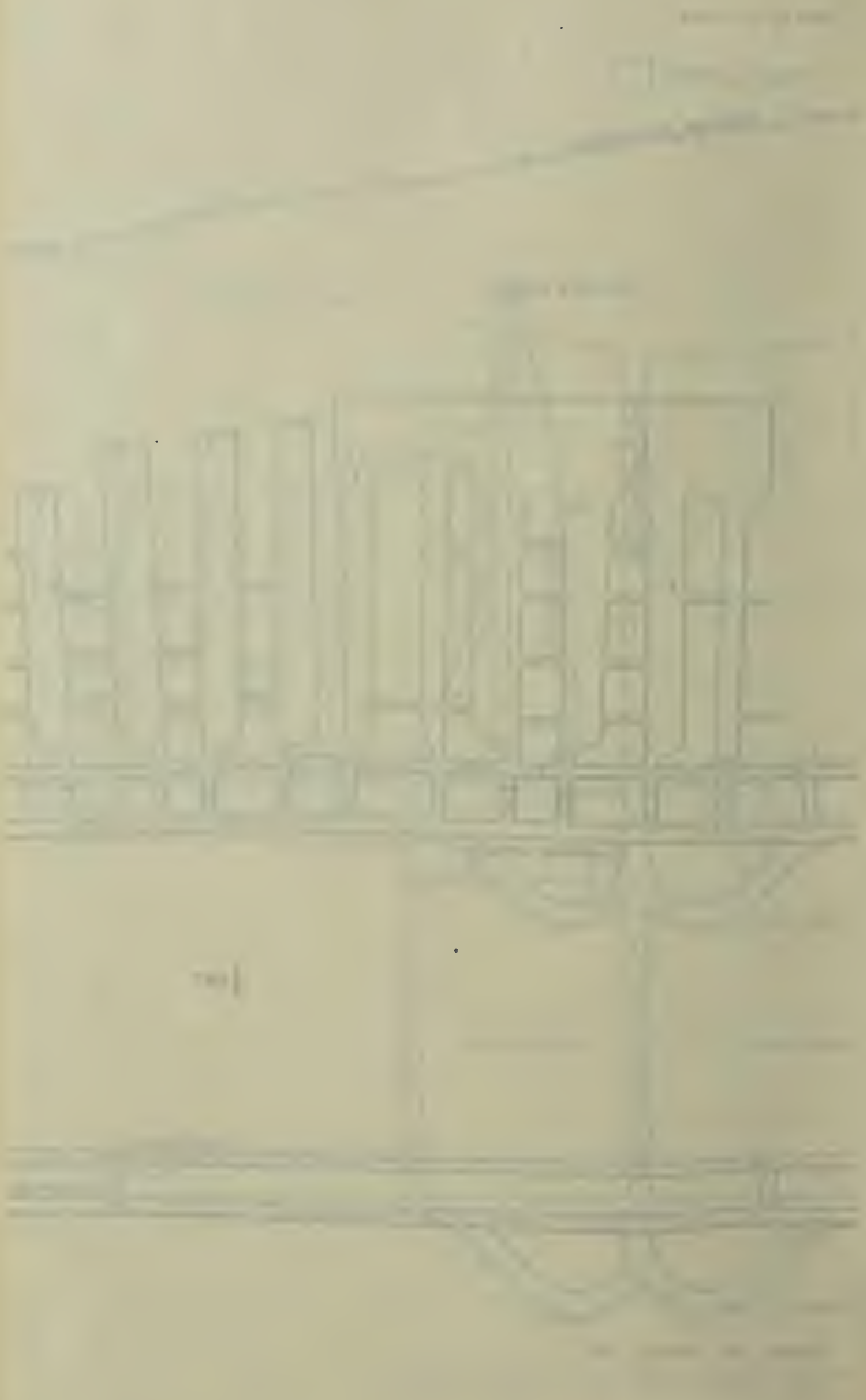
Both the advancing and retreating systems of mining are used with the breast and pillar systems. The retreating system is probably the more economical. It permits the extraction of the highest percentage of coal, but as the first cost is comparatively high, its use by some smaller companies is impracticable. At one mine where the retreating system is used, the gangway and return airway or first counter are both driven to the boundary and the breasts are then driven up the pitch to the surface pillar or to the pillar separating the workings of one lift from the gangway of the lift above. In both the retreating and advancing methods the pillars between breasts are withdrawn after a certain number of pillars have been driven to their limits.

In the breast and pillar system, as well as in the chute and pillar system, chutes from 6 to 8 feet wide are driven from the gangway to the first counter; where this is above the gangway, as it commonly is, the chutes are continued narrow for the first 12 to 20 feet above the counter. At this point, if the breast is to be wide, it is customary to begin widening and to continue gradually until the full width is reached. The breast is then carried at its full width to the limit of the lift. Faults are sometimes encountered and a narrow place about the width of the chute is driven through the faulted ground, with a manway on one side and a coal chute on the other.

The method of timbering the chutes at one mine is shown in Figure 12. The boarding on the side, commonly the inby side, of



GENERAL PLAN OF MINE USING BREAST AND PILLAR SYSTEM.



the chute is carried to the roof and serves as a brattice, the air being carried through a crosscut farther up the pitch, so that a tight partition is not necessary in the lower part of the chute. In narrow breasts the chute is commonly placed on one side and the manway on the other, but in wide breasts the chute is often placed in the center and wing chutes are used to direct the coal from the sides to the chute.

Where the dip is more than 31° and lump coal is desired, batteries, such as those shown in Figure 12, are built to retard the progress of the coal. Many of these batteries are built 50 or 60 feet apart, and when coal is to be drawn, the battery posts are removed and the coal is allowed to slide down the chute in sections as long as the distance between the batteries.

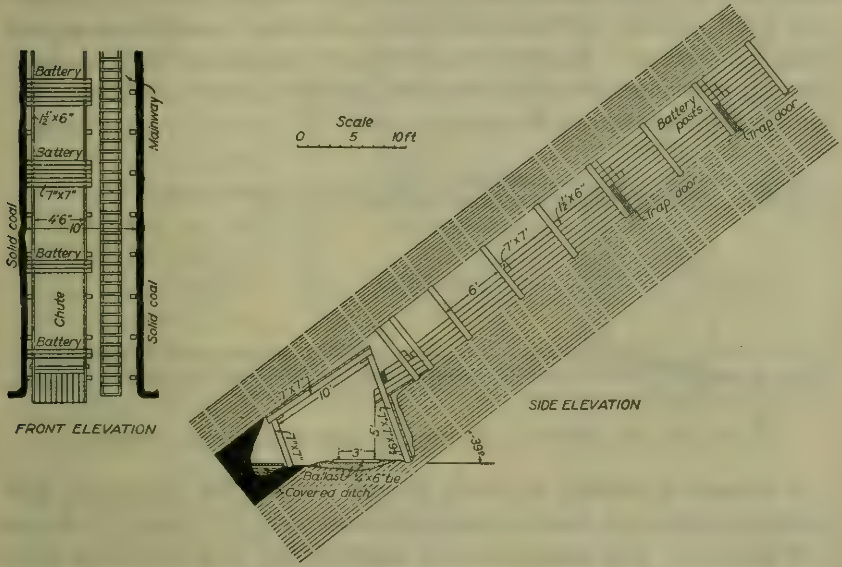


FIGURE 12.—Elevations showing method of timbering gangway and chute in coal bed with shale walls; dip, 38 to 41°.

The general plan of the main slope, return airways, turnouts at the bottom of the slope, and of gangways, counters, and breasts, are shown in Plate V. Some dimensions shown in this plate are not general, but pertain to the special mine from the map of which this sketch was made. In the mine designated, some of the breasts have not been connected by crosscuts on account of the ease of the ventilation due to the small quantity of gas. The working places can be ventilated by means of brattices. The second level gangway is shown driven with very few crosscuts, as is sometimes desirable.

The method of ventilating employed is shown in Figure 13. Though in some districts a brattice held by posts is used, it is customary here to use an air box made of boards.

PILLAR DRAWING IN BREAST AND PILLAR WORKINGS.

Where conditions are favorable, a series of breasts are usually driven either to the surface pillar or to the pillar below the gangway above. The work of pillar drawing is then begun, the breast chutes being used to carry the coal to the gangway. The work is so managed that the outby series of pillars is removed one block farther down the dip than the next series. The pillars are removed down to the block immediately above the counter, since it is considered good practice to leave this block untouched until the gangway pillars are drawn. Parts of this block are sometimes removed, leaving only a triangular pillar above the counter; frequently great difficulty arises in keeping the counter open.

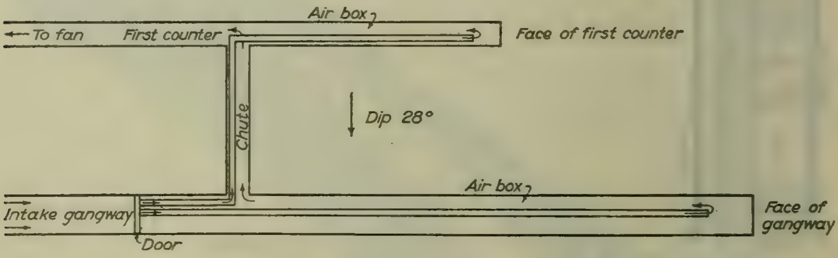


FIGURE 13.—One method of ventilating gangway and first counter faces.

A retreating system, in which breasts are worked in groups, and in which more than usual attention is paid to roof pressure is shown in Figure 14. The gangways and counters are first driven to their limits, then the rooms are turned successively, beginning at the inby end of the gangway. Pillar drawing follows immediately upon the completion of the breasts. At the point in operation that is illustrated, breasts *A* and *B* have been driven to their limits, *C* and *D* are being driven, and the drawing of the pillar at the inby side of *A* is about to begin. The drawing of this pillar begins at the upper end, the block marked *a* being removed first by driving a chute from the crosscut below the block up into it, and mining the coal so that it falls into the breast and is deflected by the wing b_1 into the coal chute. After block *a* is removed, block *b* is attacked in the manner shown by the dotted line, the coal being directed into the coal chute by wing b_2. Succeeding chutes are removed in the same way. By using this system it is possible to drive breasts 70 feet wide, and to regulate the roof pressure so that little powder is used.

The small pillars shown in breasts C and D are left to support the roof in the neighborhood of a fault, as the roof is more difficult to control there than in other places.

Some of the details connected with the working of a 70-foot breast are shown in Figure 15. The face is cut by a post puncher to a depth of about 8 feet, then two 6-foot holes are drilled—one on each side of the breast—which, combined with the roof pressure, break down the coal. These machines, which are driven by compressed air, have given satisfaction where they have been used. Seven set-ups, as indicated, are needed to cut the 70-foot face. Figure 15 shows the method of ventilating the face, the construction of chutes and wings, and the batteries for supporting the wings.

An interesting method of applying the breast and pillar system is shown in Figure 16. The arrangement and dimensions of gang-

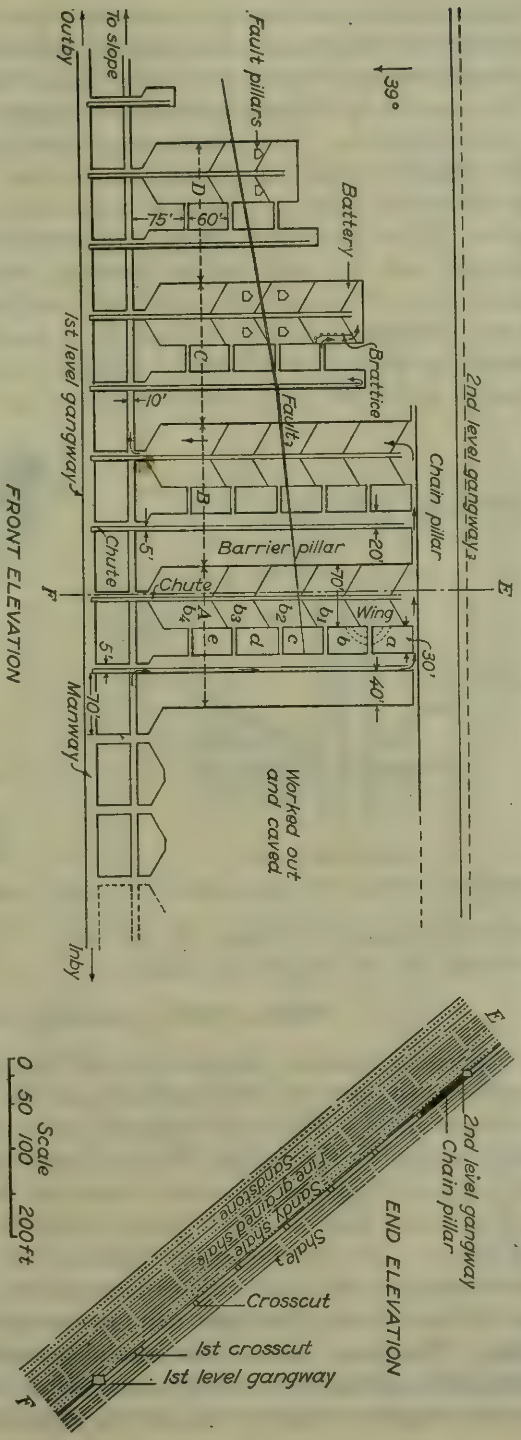


FIGURE 14.—Method of working coal bed 5 feet 8 inches thick; top and bottom shale; dip, 39°; produces some gas.

ways, counters and narrow connections, or necks between the first counter and the breast is that usually followed in the district, but the pillars between breasts are much larger than those ordinarily left. This practice is followed because of the great depth of cover above this part of the mine. The breasts range in width from 25 to 40 feet, and the pillars between them from 60 to 100 feet. In one level the breasts are driven in pairs as indicated, with solid pillars between adjacent pairs. When the pillars are to be removed they are split with 20-foot breasts, and the solid pillars between breasts are attacked in the same way. The coal bed where this method is applied averages 6 feet in thickness and is overlaid by a massive sandstone roof. In removing these pillars, severe "bumps" occurred which resulted in several fatalities. The cover ranged from 1,500 to 2,000 feet. At present the plan is to mine 60 per cent of the coal on one advance and leave 40 per cent in for support.

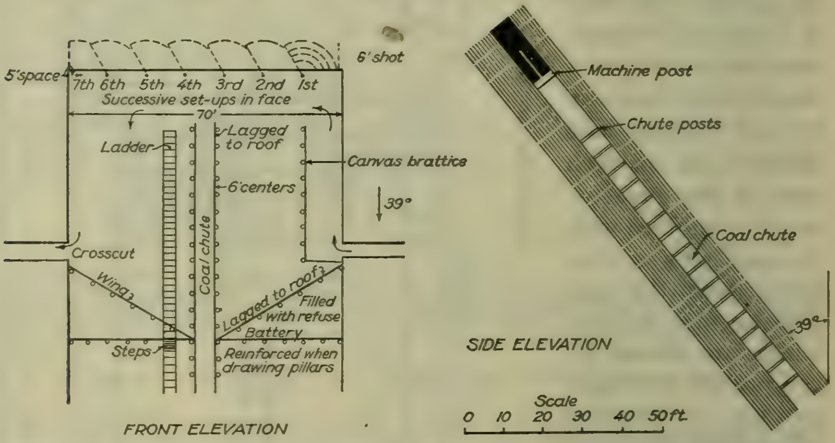


Figure 15.—System used when mining with Sullivan post punchers in 70-foot breasts.

SPECIAL CHUTE AND PILLAR SYSTEM.

Figure 17 shows a special form of the chute and pillar system employed to meet unusual conditions at the Taylor mine. The bed averages about 5 feet in thickness, dips about 70°, and has two good shale walls, but the coal is disturbed greatly by igneous intrusions. Development follows the usual custom as far as slopes, gangways, and counters are concerned, but it differs in the method of driving the chutes. Six-foot chutes are continued up the full pitch of the bed for a distance of 18 feet above the counter, where diagonal chutes are driven in both directions, making an angle of about 100° between them. The main part of the chute is continued in this direction diagonally up the pitch inby; at intervals of 50 or 60 feet along these chutes diagonal crosscuts are driven approximately at right angles to the chute. In other words, the chutes are driven at an angle of about 50° with the dip. When a large dike is encountered only part of the chute is driven through the igneous rock, and then the diagonal system of chutes and crosscuts is again followed.

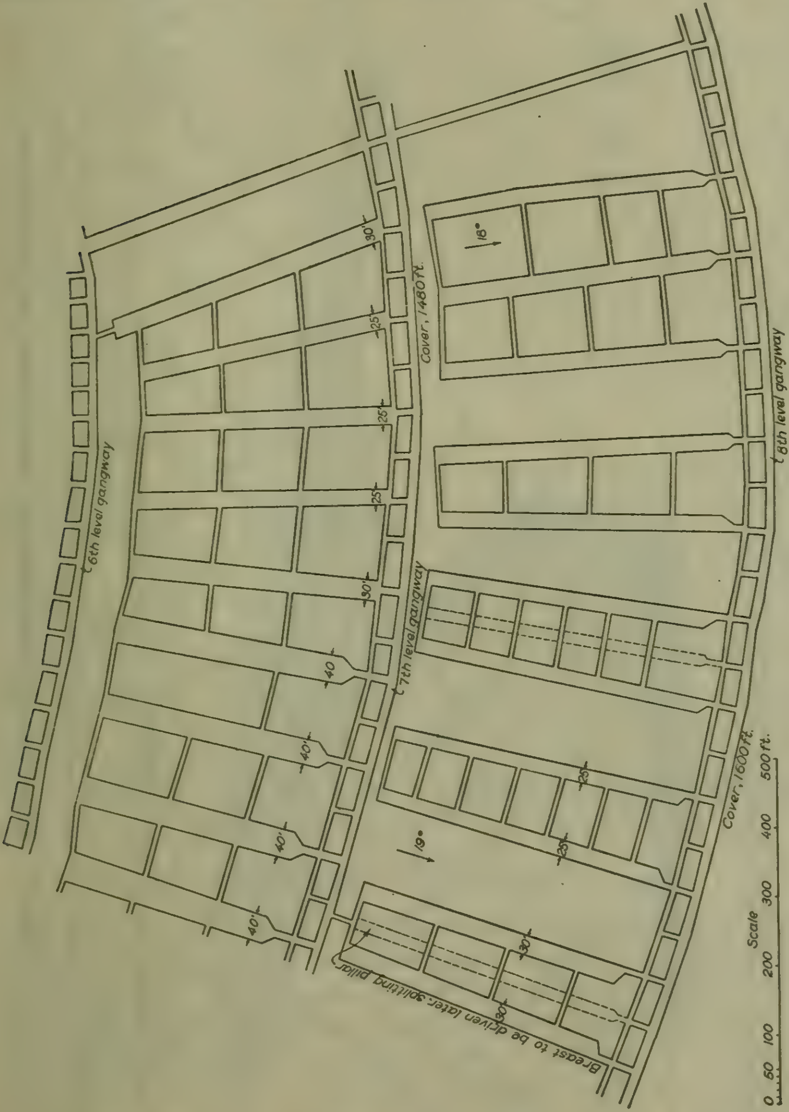


FIGURE 16.—Breast and pillar system of working 6-foot bed; good sandstone roof; dip, 18 to 19°.

In ventilating under these special conditions the slope is generally the intake, and from it the air passes along the gangway to the inby end, then up through the last counter to the chute or breast, in which it is directed by a brattice to the working face, then down the other side to the nearest crosscut, and so on out to the return airway.

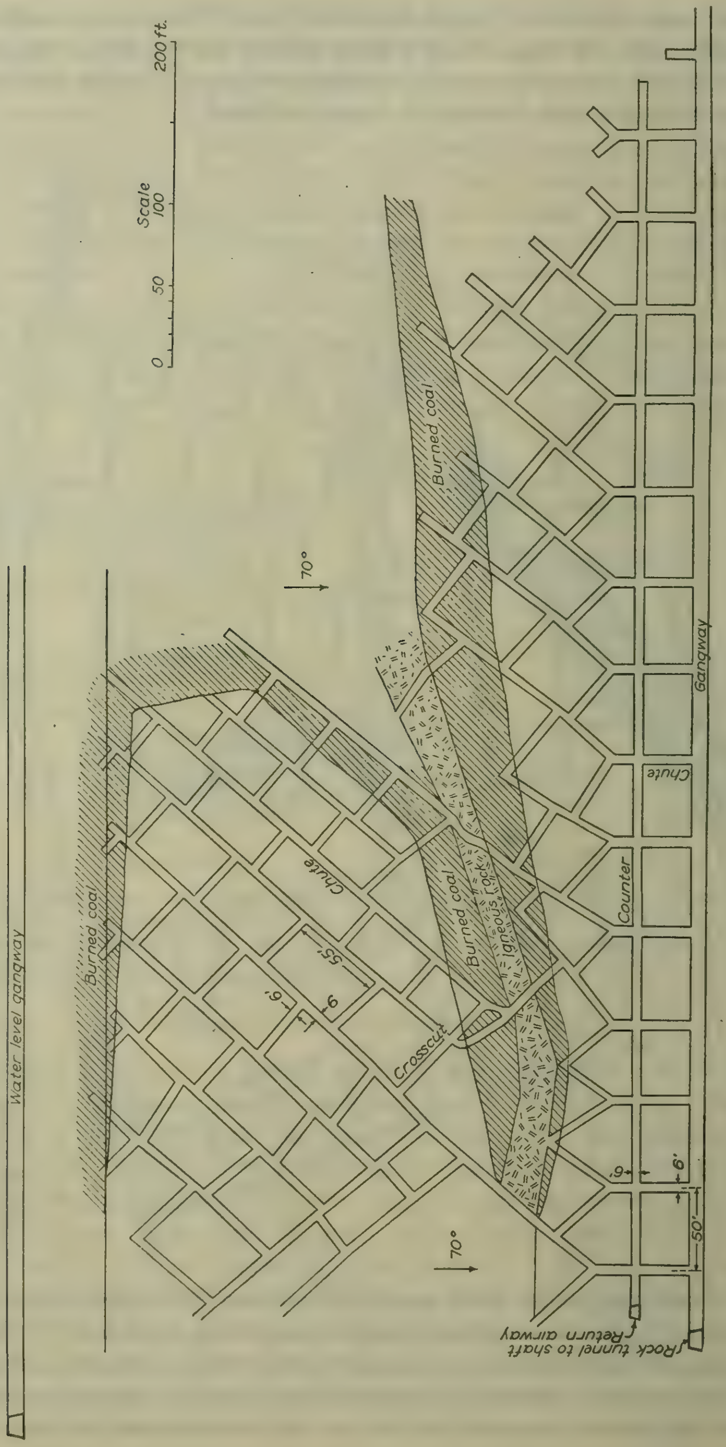


FIGURE 17.—Special chute and pillar system with diagonal chutes; used in Taylor mine.

LONGWALL SYSTEM.

The longwall system is always interesting, because of the complete extraction which it allows. An adaptation of this method within a panel was tried at one of the mines, as shown in Figure 18. The bed in this place is about 6 feet in thickness, dips at an angle of 39°, and is immediately overlain by 27 feet of bone and carbonaceous shale, above which is a main roof of jointed sandstone 25 feet thick.

This method is a modified chute and pillar system in connection with longwall. The gangway and first counter with the connecting chute were driven as usual, and the chutes or narrow breast were continued up the pitch. There are two blocks above the counter. The upper end of the second block was cut at an angle of about 45° with the direction of the chute, as shown in the figure, and the longwall face was started at this point and carried in steps 6 feet in length each way. The loading chute was parallel with the longwall face and was protected by 6-foot cogs set close together parallel to the chute. The first roof caved immediately back of the cogs.

This method could not be applied successfully as roof pressure could not be regulated, and squeezes occurred which temporarily destroyed the face. The sandstone stratum was probably responsible for this condition, as it broke in blocks instead of applying a uniform pressure. This method was replaced by the usual breast and pillar system. Further experiments should be carried out with the longwall method, covering cost, completeness of extraction, and safety to the men. Many coal beds of the State extend to great depths, and the great weight of the overburden makes the application of breast or chute systems very costly, if possible at all. Apparently the longwall method must be adopted if these deep beds are to be mined. All data that can be gathered from experiments will be useful when exploitation of deeper parts of the beds is undertaken.

SURFACE SUBSIDENCE AND DRAINAGE.

In Washington, except in rare instances, the maintenance of the surface in an undisturbed condition is not requisite. In this respect, conditions of the coal industry of the State differ greatly from those of some other districts in which the desirability of leaving the surface undisturbed is so great that large quantities of coal are left in the ground as pillars. In Washington permanent pillars are not left unless it is necessary to protect railroads, streams, or important buildings. Subsidence frequently results in serious increase in expense for draining the mines.

In mining the first lift, called the water level, it has been the custom to drive working places to the surface, and then to extract as much pillar coal as possible. As a result the surface subsides along

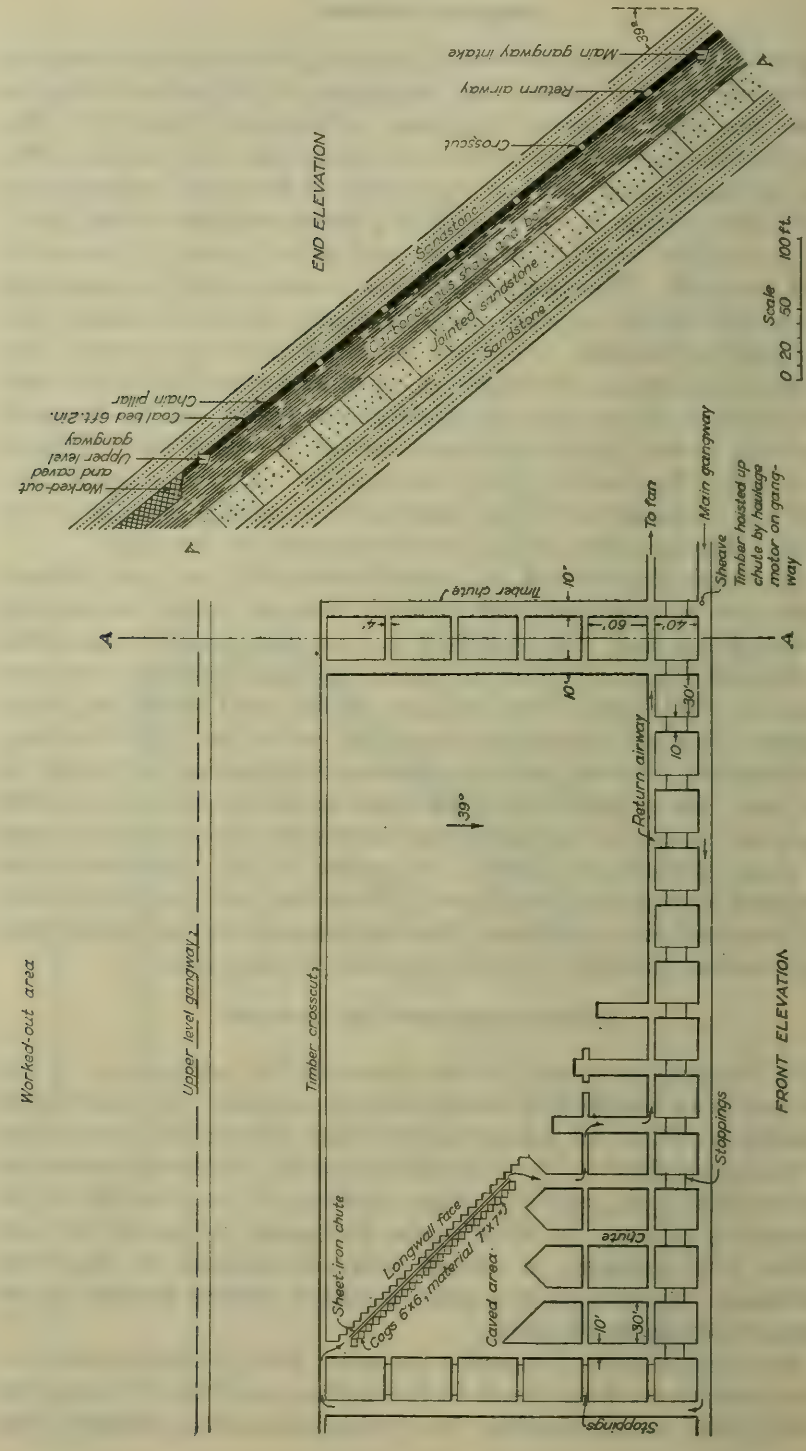


FIGURE 18.—Panel longwall system for coal bed 6 feet thick; dip, 39°; roof, bone and carbonaceous shale, 27 feet thick; sandstone over bone.

the outcrop into a series of catch basins, from which water enters the mines. This subsidence might not be serious if the water-level gangways were kept open and the pillars below them remained uncracked, as the water would then drain out to the surface. Frequently, however, these gangways have not been kept open, and sometimes it might be impracticable to do so. In some mines, moreover, the barrier pillar or chain pillar below the gangway is so badly robbed that it no longer protects the lower workings from the surface water. All the water that penetrates below the water-level gangway has to be pumped out, thus increasing the cost of operation. Even when the water-level gangway is kept open trouble may arise from water entering as a result of subsidence. When the area below water level has been worked to a considerable extent and the pillars have been drawn, the roof caves and the resulting cracks reach upward for a great distance, sometimes for several hundred feet. These openings extend up the pitch beyond the barrier pillar and act as channels through which the surface water can reach the lower levels. As a remedy for the entrance of water from the surface it is suggested that if possible the entire water-level lift should be left intact until the property is to be abandoned. Had this system been practiced in King County and in Pierce County, several mines would have been free from the heavy pumping charges that burden them.

UNDERGROUND WATERS.

What has been said concerning the entrance of water from the surface into mine workings applies to the coal areas in King County. In certain areas in the Green River district, especially in the area north and south of Green River, east of Franklin and the Cannon mine, numerous underground streams occupy preglacial channels.

Prior to the glacial period the streams had cut well-established channels in the surface of the coal field as it then existed. During the glacial period these channels were filled with débris and the whole surface was covered with a mantle of drift. This drift hides the topography of the bedrock—which has little relation to the present topography—and the channels of the underground streams can not be located from an inspection of the surface.

Surface streams coming from the foothills of the Cascades enter this area of glacial drift and sink to the preglacial channels. The waters of such streams as Durham Run, Dick Run, and others in the Durham district, as well as Deep Creek entering Deep Lake, and Coal Creek, sink thus into the ground. In addition to these streams are several small ones that sink into this natural gravel filter. In some instances these channels have been eroded to the present depth of Green River, as is shown by streams entering that river through the gravels in Secs. 8, 9, 10, 17, and 19, T. 21 N., R. 7 E. In a mine approaching the level of Green River within these areas precautions must be taken against breaking into one of the preglacial channels, thus endangering the lives of men and perhaps flooding the property. On three occasions the mine workings have approached too close to the contact between bedrock and the mantle of drift, and two mines were flooded completely and another was saved only by its water-level opening. Consideration of these conditions will become increasingly important in the future, as the more available coal within the other areas becomes exhausted. The advisability of formulating and adopting a general plan for draining the entire field might well be considered. Suitable drainage tunnels should be planned for, and the elevation of the bottoms of slopes to be sunk in the future should be such that the water from the lowest gangways would drain into the proposed tunnels. Furthermore, main haulageways and other gangways might be driven with the object of drainage in view, and any rock tunnels driven for prospecting or for development should be driven also according to some definite plan. If these principles are followed, there will eventually be gangways and rock tunnels so placed and constructed that the water can be drained into a joint drainage tunnel. The industry, of course, does not depend upon this program at present, yet the writer is convinced that much property and many lives will be saved in the future if some such plan is agreed upon.

UNDERGROUND HAULAGE.

The use of mules is confined principally to the gathering of cars, though in many of the smaller mines mules are still used to haul the coal in the mine and to haul it to the surface. Trolley-type electric locomotives are used in most mines. Storage-battery locomotives have been introduced in recent years and are meeting with favor. Gasoline locomotives are also used, and then the main haulageway is also the return airway.

The tracks are laid with 20 and 30 pound rails, and 4 by 6 inch ties are commonly used. In general, more attention should be paid to the building and maintenance of good tracks, although some mines in King County leave little to be desired. Where track construction is given proper attention, with regard to alignment, grade, and ballasting, fewer delays occur from wrecks than in mines where tracks are poor.

In both chute and breast workings the coal cars are loaded at the gangway by loaders, who assist also in making up the trips. The coal sometimes becomes blocked in the chutes, and the loaders have to find the seat of trouble and to start the coal moving. In mines where much trouble of this sort is experienced chute starters are employed. Many haulageways are lighted their entire length by electric lights, but many mines have lights about the bottom of the slopes only.

MINING AND BLASTING.

During 1917, 44.90 per cent of the coal was mined by hand, 35.82 per cent was shot off the solid, and 19.28 per cent was mined by machine. Of the explosives used, 87.7 per cent of the total was dynamite, 11.7 per cent permissible explosive, and only 0.6 per cent black powder.

Only one type of mining machine is used in King County, namely, the post puncher. In a mine where a 70-foot breast is worked and the coal is 5 feet 8 inches thick, dipping 39°, one man cuts 270 square feet in eight hours. In another mine where the bed dips 27° two men make a cutting 7 feet deep across a 20-foot face, or 140 square feet, in three hours. In the latter mine two 6-foot holes are drilled near the top and near the corners of the rooms; also two holes near the bottom and near the corners, these holes being loaded with two sticks each of a permissible explosive.

TIMBERING.

The kind of timbering employed has already been mentioned. In most mines gangway sets are made of second-growth fir, ranging from 10 to 24 inches in diameter. In chutes and breasts round props ranging from 6 to 10 inches in diameter are used. In some districts round props have become scarce, and props are used that have been split from larger fir trees. The lagging used is commonly 2 inches thick and from 8 to 10 inches wide. This material is generally split from larger fir trees, sometimes from cedar trees. Hemlock is employed occasionally for building cogs, but its use is avoided if possible.

In some mines sawed lumber is widely used, and in many slopes square timber is used instead of round. The slope sets are usually in three, four, or five pieces, depending on the size of the slope and on the use of mud sills. The collars are usually made of 12 by 14 inch timber with a 2-inch notch at each end; the legs are usually 12 by 12 inches; and where mud sills are used they are usually 10 inches thick by 12 inches wide, with notches at each end to receive the legs.

Washington is well provided with timber, especially in the area west of the Cascade Mountains. In King County the coal areas were originally well timbered with fir suitable for mining use, but that readily available has been exhausted in the vicinity of some of the older mines, and it is now necessary to haul the timber for considerable distances by motor truck or to ship it by rail.

VENTILATION.

In the early days of coal mining in Washington, the homemade paddle-wheel fan was commonly used, being replaced later with the large slow-running steel fan. More recently the modern high-speed multiblade fan has been installed in several mines and has met with favor. Disk fans are used in some of the smaller mines.

The method of ventilating three coal beds that are worked simultaneously is shown in Figure 19. The main haulageway is driven on the upper of the three beds, and at intervals of 1,000 feet rock tunnels are driven from this bed to underlying beds; then all the coal in the lower beds in the panel between adjacent rock tunnels is mined out, and that part of the mine is sealed off. The main haulageway is the intake, and the air is split at the rock tunnels, part of it traveling through the workings of the upper bed, and the remainder ventilating the workings in the lower beds. After it has traveled over the working faces, the air in the lower beds passes through the return airway, which runs parallel to the gangway, to a rock chute. Through the chute the air passes to the main return airway in the upper bed, through this up the pitch to a rock tunnel, and by the tunnel to the main return airway leading to the fan.

OVERCASTS.

The part of the overcast next to the gangway is sometimes built of wood, but here it is faced with fireproof material. The overcasts are frequently constructed of concrete from the floor of the bed up to the overlying material, thus making the entire construction fireproof.

STOPPINGS AND AIR DEFLECTORS.

Permanent stoppings between the main and the return air courses are usually built of wood blocks, with a coating of cement on each end. When coal is being loaded through the chute connecting the return airway with the gangway that part of the chute is kept full of coal; in addition, one or two drop curtains are placed within the coal chute. Two trap doors are usually built in the manway section of the chute, about 10 or 12 feet apart. In the crosscuts between chutes or breasts board stoppings are frequently built; at times canvas drop curtains are used, especially if the mine is wet; at other times the crosscuts are allowed to fill with loose coal from the coal chutes.

DOORS.

All doors on the main haulageways are built to close automatically. They are placed far enough apart to permit the passage of the longest trips without having both doors open at the same time.

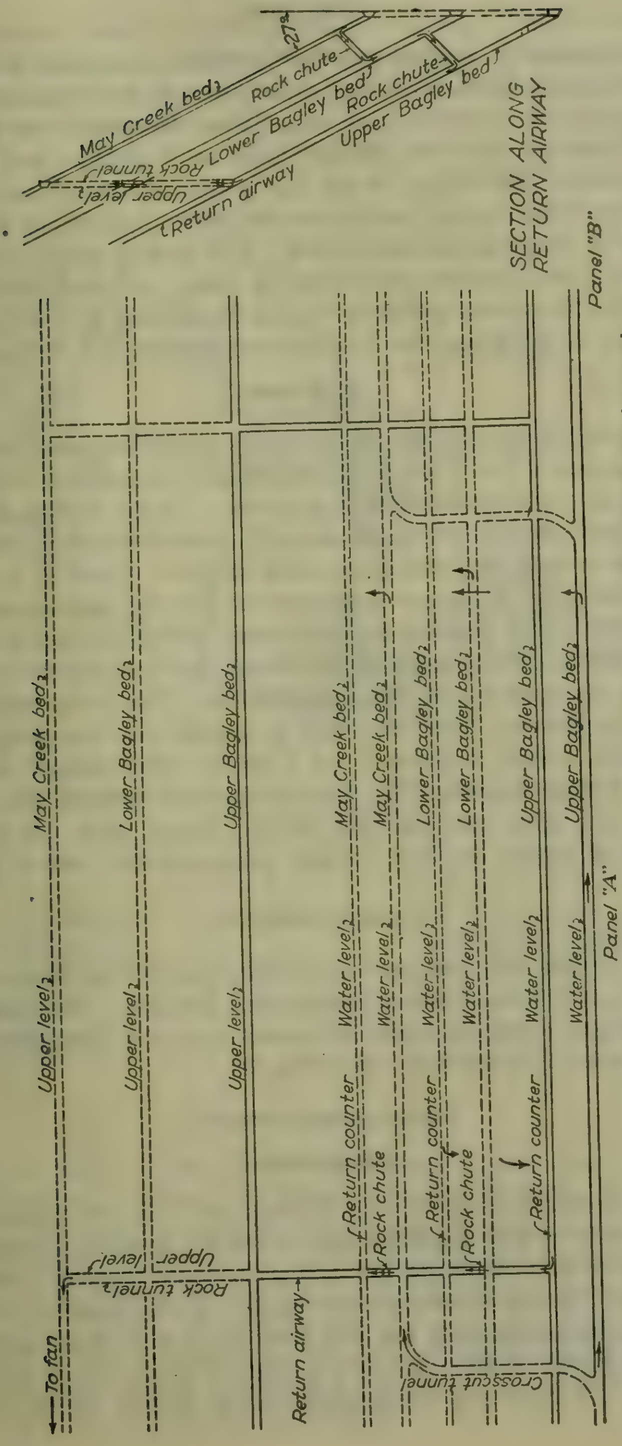


FIGURE 19.—Method of ventilating three beds that are being worked simultaneously.

MINE FIRES.

King County in general has little trouble from mine fires, as the necessary precautions have been taken, though four mines—the Old New Castle, the Lawson mine near Black Diamond, the No. 14 at Black Diamond, and the McKay mine at Franklin—had fires for several years. The origin of the fire at the Old New Castle mine is not known to the writer, but fires at the other three mines were probably due to spontaneous combustion. The McKay bed at these three places has two benches, separated by bony coal and carbonaceous shale. The fires were probably caused by heating in this parting or in the coal of the upper bench which caved in the old workings.

MAN CARS.

No special provisions are made at most mines for handling men on the slopes, but at No. 11 mine, Black Diamond, a man car invented by a blacksmith, Joseph Klansnick, is in use. On the bottom of the car are two steel plates to which are securely attached dogs so shaped and placed as to sink into the guide rails or ties. When in a running position the body of the car is elevated so that the dogs do not touch, and is held in this position by levers and chains connected with the hoisting cable. If the cable should break, the body of the car would drop and the dogs would come into action. The writer witnessed a test at the Burnett mine in which an empty car was stopped and held firmly within a distance of 6 inches after release from the cable on a slope dipping 46°. Cars enough are used in No. 11 mine to carry the men into and out of the mine; their use decreases the time of travel one-half besides giving to the men a sense of security.

PIERCE COUNTY.

Pierce County contains two coal fields—the Carbon River and the Nisqually—lying southeast of Seattle and Tacoma. The area of the Carbon River district is about 53 squares miles; in this district only is coal now being produced. (See Fig. 20.)

CARBON RIVER DISTRICT.

TOPOGRAPHY.

In the northern part of this district the hills are rounded and extend merely a few hundred feet above the general gravel plain. To the south and southeast the surface is more rugged. The foothills of the Cascade Mountains are reached at Carbonado; farther to the southeast, at Melmont, the coal beds lie in a mountainous region with hills rising on the east to a height of nearly 2,500 feet above sea level. Fairfax and Montezuma, lying farther south, are also well within the foothills of the Cascades. Carbon River and its tributaries, South Prairie and Gale Creeks, have cut deep gorges in which the coal measures are exposed. Some of these canyons along Carbon River are 400 to 600 feet deep.

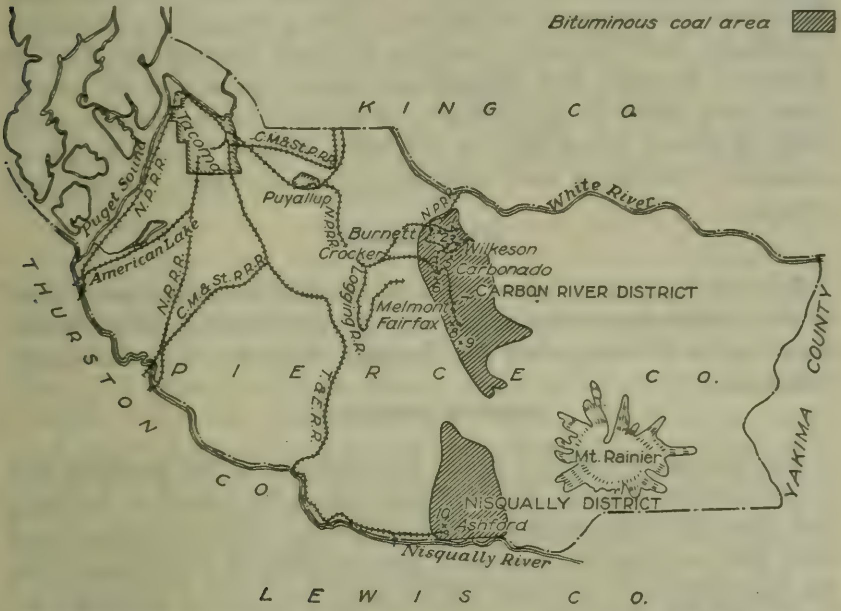


FIGURE 20.—Outline map of Pierce County showing coal areas, situation of mines, and lines of transportation.

No.	Name of mine.	Name of company.
1	Morristown mines	South Willis Coal Co.
2	Burnett	Pacific Coast Coal Co.
3	Gale Creek	Gale Creek Coal Mines Co.
4	Champian	South Willis Coal Co.
5	Wilkeson	Wilkeson Coal & Coke Co.
6	Carbonado	Carbon Hill Coal Co.
7	Melmont	Do.
8	Fairfax	Fairfax Mine (Inc.)
9	Montezuma	Pacific Coal & Lumber Co.
10	Ashford	Mashel Coal Co.

STRUCTURE.

The coal fields of this district have been thrown into a series of close folds and have been subjected to much faulting. In the area north of Melmont the axes of the folds strike generally in a northwesterly direction and plunge to the northwest; but south of Melmont the axes have a more northerly direction, and several of them plunge to the south. Five anticlines and four synclines have been recognized within a distance of 2½ miles east and west. These folds are compressed closely and some of the beds dip at angles nearly vertical, but the usual dip is 30° to 65°.

Many faults have been observed, most of which are overthrusts, though some are normal. The displacement along normal faults is less than along thrust faults. In general the faults strike in a direction parallel to the axes of the folds. The intense folding has apparently affected the quality of the coal, which is bituminous. The lowest beds contain coking coal. Coke is produced at Wilkeson, Carbonado, and Fairfax. Near the southern limit of the field—at Melmont, Fairfax, and Montezuma—recent intrusions of igneous rocks have added to the difficulty of mining; farther south, at the head of Evans Creek and in Puyallup Valley, intrusions are so numerous that many coal beds have been rendered commercially valueless.

STRATIGRAPHY.

The coal measures of the Carbon River field have been subdivided by the United States Geological Survey [6] into three parts which are, from top to bottom, called the Burnett, Wilkeson, and Carbonado formations.

BURNETT FORMATION.

The Burnett formation, which is recognized in the northern part of the district, contains the coal beds now being mined at Spiketon and those formerly worked at South Willis. Twelve beds of coal, bony coal, and impure bone have been crosscut or developed within the properties of the South Willis Coal Co. The Pittsburgh bed with 7 to 8 feet of coal, the Champion bed with 5 feet 7 inches of coal and bone, the Windsor bed with 4 feet 1 inch of coal, and the Acme and Peacock beds have been mined more or less within this property. These coals have not been distorted as greatly as those of the lower beds in the Wilkeson and Carbonado formations, but the coal is not as good as that in lower formations. There is, however, some good coal in these beds, though in general the ash is high. The beds dip eastward at an average angle of about 60°.

WILKESON FORMATION.

The Wilkeson formation, as described by the United States Geological Survey, lies between the thick bed of massive sandstone above the Miller bed and a bed of shale between the Miller and Wingate beds. The Miller coal is the only one of much commercial value that has been found and developed within this formation. This bed contains 4 feet 3 inches of coal of good quality, which is popular in the domestic market.

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[6] Willis, Baily, Tacoma Folio 54, U. S. Geol. Survey, 1896.

CARBONADO FORMATION.

By far the largest part of the coal produced in Pierce County is taken from the Carbonado formation, within which occur the well-known Wilkeson coking coal beds, as well as the Wingate and some others less known. It is difficult to construct a connected section from the base of the Carbonado to its top. The writer has measured the section within the Carbon River canyon as far as possible and then continued the measurements within the Carbonado mine, observing within this section 11 beds that might prove commercially profitable. In addition to these beds of coal and bone are other beds of impure bone and carbonaceous bone.

The uppermost bed is the Wingate, which is from 4 feet to 5 feet 8 inches in thickness. According to the new system of numbering, No. 10—approximately 250 feet below the Wingate—has 3 to 4 feet of coal. No. 9, 190 feet below No. 10, is 5 feet 1 inch to 7 feet 5 inches thick. No. 8, approximately 160 feet below No. 9, is 8 feet thick. No. 7, the Gem of the earlier nomenclature, 35 feet below No. 8, ranges from 2 feet 3 inches to 3 feet 7 inches. No. 6, 55 feet below No. 7, is 3 feet 4 inches thick. No. 5, 40 feet below No. 6, is 7 to 8 feet thick. No. 4, 105 feet below No. 5, is 4 feet thick. No. 3, 40 feet below No. 4, has 5 feet of coal and bone. No. 2, 85 feet below No. 3, is 10 feet thick and contains 6 feet 3 inches of good coal. The lowest coal of this series is No. 1, concerning which very little is known.

All coals of the Carbonado formation that have been mined at the Carbonado mine doubtless have their corresponding representatives in the Wilkeson, Gale Creek, and Burnett mines. The Nos. 8 and 9 beds of the new system at Carbonado are worked extensively at Wilkeson as No. 2 and No. 3, respectively. Beds 8, 9, 11, and 12 of the new system have been worked extensively at Burnett as Nos. 4, 3, 2, and 1, respectively.

MELMONT FORMATION.

The exact relationship between the coals exposed in the Melmont workings and in the base of the Carbonado formation has not been determined. Between the workings at Carbonado and those at Melmont there is a large sill or dike of igneous rock apparently occupying a fault plane. The character of the shales and sandstones at the two workings indicates that those of the Melmont mine belong to a lower zone than those of the Carbonado formation, for the shales at Melmont are more slaty and the sandstones are more indurated than are those of the Carbonado formation. When the stratigraphy is definitely worked out it will probably be found that the Melmont beds and some of those at Fairfax and Montezuma belong to a lower series than those exposed at Carbonado, Wilkeson, and Burnett.

Within the Melmont mine Nos. 2, 3, 5, and 6 beds have been more or less developed, most work having been done on No. 3. Bed 2 contains more than 9 feet of material between walls, 8 feet 9 inches of which is coal. Bed 3 is over 11 feet in thickness between walls, with 6 feet of coal of fair quality. No cross sections of beds 5 and 6 are available. The Northwestern Improvement Co., which formerly operated the Melmont mine, finally abandoned the project, even after great expenditure in driving rock tunnels and slopes and erecting an expensive cleaning plant, because of the disturbed condition of this part of the field.

FAIRFAX MINE.

Fairfax mine lies about 2 miles southeast of the Melmont. Thus far the relation between the coals of the two operations has not been demonstrated, but probably a close relationship exists. Four anticlinal and three synclinal folds have been observed within a space of less than one-half mile in the present workings of the Fairfax mine. It has not yet been determined whether these are true anticlines and synclines or are parts of fault blocks that have been forced into these apparently folded conditions. At this mine, development work has been done on beds A, Rust No. 1, Rust No. 2, and No. 5, but nearly all of this work has been done on the No. 5 bed, which is 9 feet thick and contains 5 feet of coal. On account of the faulted condition, the relationship of these beds is not yet known. The coal from the Fairfax mine is of good quality, has been extensively used as a blacksmith coal, and makes good coke.

MONTEZUMA MINE.

The Montezuma mine which lies south of the Fairfax mine contains, to a large extent at least, the southern continuation of some of the beds worked at the Fairfax. This coal also is difficult to work because of geologic disturbances.

NISQUALLY DISTRICT.

At the southern boundary of Pierce County extending northward from the Nisqually River lies a coal field containing, approximately, 43 square miles of coal-bearing land. The surface of the Nisqually coal field is more rugged than that of any other field in Washington with the possible exception of the anthracite district along the northern slope of Mount Baker. The hills rise abruptly from the Nisqually River and its tributaries, such as Mashell and Busy Brook Creek, which have cut deep gorges across the coal measures. This roughness of topography renders transportation very expensive. The structure of this field is evident along the banks of Busy Brook Creek, where numerous faults and folds are shown, as well as a greater number of intrusions than are observed in any other part of the Washington coal fields, with the exception of those in the vicinity of Barneston in King County. No attempt has been made to work out the stratigraphy of this district in detail, as development has not progressed enough to expose the beds adequately for study.

The Nisqually Chief coal bed, which has been developed more than any other within the field, is 15 feet 6 inches in thickness and contains over 14½ feet of a good grade of bituminous coal which has coking properties. Other outcrops are exposed along the Busy Brook, but because of the extensive faulting it is not known how many coal beds exist. Numerous outcrops are found in the northern part of the district, especially along the upper tributaries of the Puyallup River, but systematic work is almost precluded by their inaccessibility. No commercial mine has been developed in this field.

MINING METHODS OF PIERCE COUNTY.

The beds in Pierce County dip in some places at such steep angles and are in places so folded and faulted that mining methods are far from simple. A greater number of methods are probably employed in the Wilkeson and Carbonado districts than in any other coal district of equal size in the United States. Most of these methods have been described already under the chute and pillar, breast and pillar, and long wall systems. Only those operations that are significant because of their departure from the established methods will be described in detail.

QUALITY OF COAL.

In the Burnett series, where such beds as the Lady Wellington, Champion, and Pittsburgh have been mined, the coal is rather high in ash, but it can be mined more cheaply than in some other districts. This coal is noncoking and is used principally for generating steam and for domestic fuel.

The Wingate (Burnett No. 2) and Miller (Burnett No. 1) beds (See Pl. VI), which have been mined at Burnett, Gale Creek, and Carbonado, contain coal that is popular for domestic purposes and for steaming. The other beds, except those yielding coking coal, produce fuel used primarily for generating steam and for domestic fuel. Two beds within this series, frequently referred to as Wilkeson No. 2 and No. 3, contain coking coal from which a high grade of coke is made. The beds mined at Fairfax and those formerly mined at Montezuma also contain coking coal. Some of these coking coals are also used in by-product ovens in the manufacture of city gas, the resulting coke being a more or less secondary consideration. Some of the coal is used in the Northwestern States in blacksmithing.

FORMS OF OPENINGS.

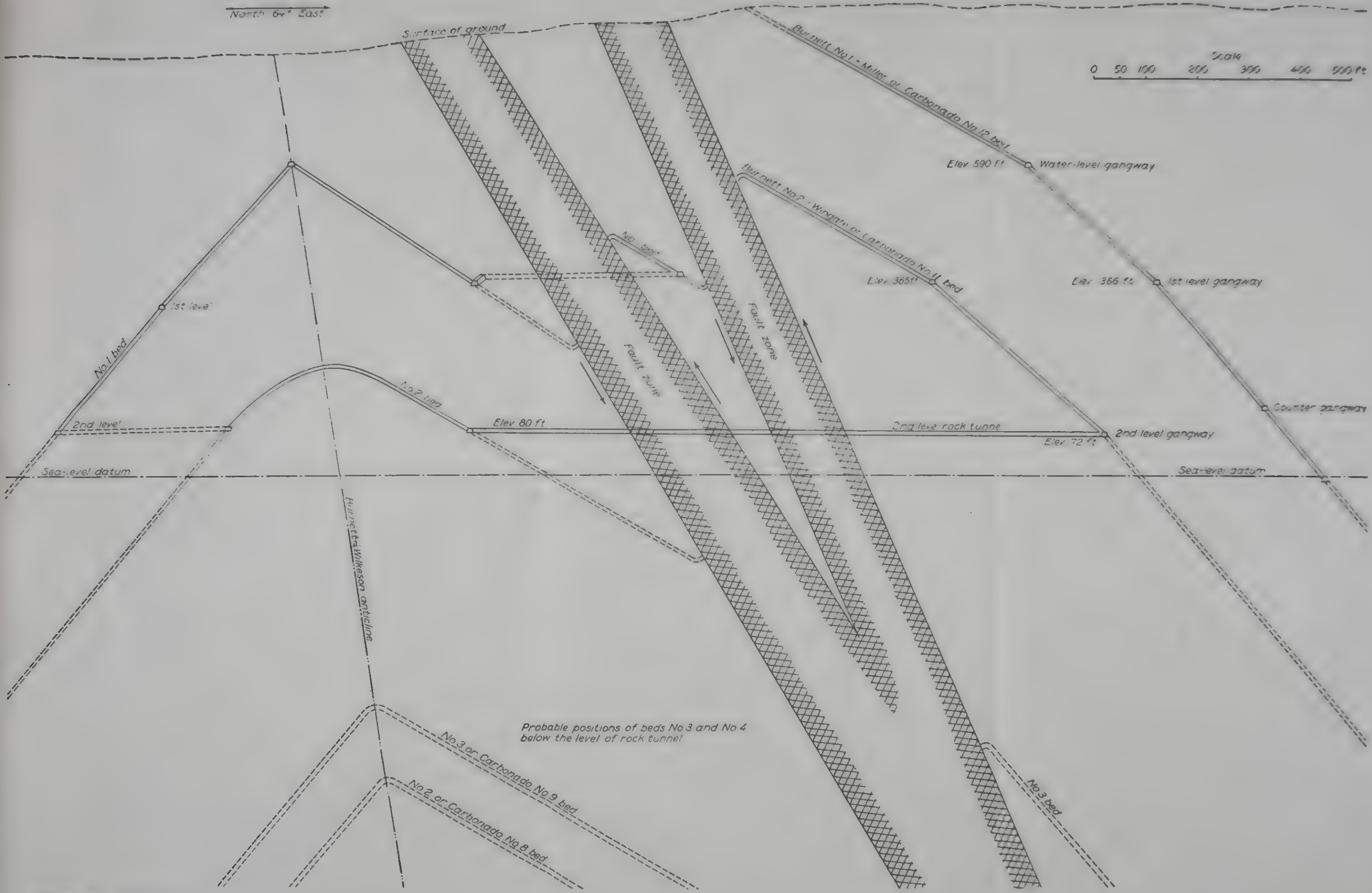
During early coal mining in Pierce County gangways were driven at water level on the outcrops of accessible beds, those not directly accessible being reached by driving rock tunnels. The land areas range from 400 to 800 feet above the levels of the streams, and a large quantity of coal lies above water level, though that remaining is largely second grade and is considered a future reserve as long as coal of higher grades is available. The better grades of coal—such as those contained in the Miller, Wingate, and Wilkeson No. 2 and No. 3 beds—have been almost exhausted above water level within accessible coal areas, hence extensive surface transportation must be developed before the remaining coal will be available. As the coal above water level became exhausted, that lying below it was attacked commonly by slopes sunk on the full dip of the bed. In some instances where the beds dip at high angles the slopes have been sunk across the dip to facilitate construction, repairs, and haulage. Up to 1919 no shafts had been sunk in the field, but at one mine, where the beds dip at high angles, it is planned to sink a shaft near the center of an anticline and to reach the coal by rock tunnels.

SURFACE TRANSPORTATION.

The entrance of the mine is usually not far from the cleaning plant and the railroad, therefore surface transportation presents little difficulty. In one case, however, the entrance to the mine is 3,000 feet or more from the cleaning and shipping point, and the topography is such that a tramroad had to be built partly through tunnels and partly along the sides of cliffs. This road has caused so much expense and trouble that the company has seriously considered the additional expenditure of building a continuous tunnel. The Montezuma mine is some distance from the railroad tracks, and the topography is such that a surface road could hardly be constructed. The coal was flushed down a sluice from the cleaning plant to the bunker on the railroad track.

GENERAL PLAN OF WORKING.

Most slopes are double track and are laid with 30-pound rails. In some places the slopes are timbered with three-piece sets, and in others the roof is so good that a collar is not necessary and only side legs or props are used. In two mines the slopes are driven diagonally across the dip and the turnout is made directly into the coal bed.



42456°—24. (Face p. 48.)

STRUCTURAL RELATIONSHIP OF COAL BEDS MINED AT BURNETT, PIERCE COUNTY

In another mine the slope is driven on the dip and the turnout is made in overlying material. A safety stop is placed at the top of each slope.

Gangways are generally driven on the strike with a grade of approximately 1 per cent, a good ditch being usually carried on the dip side. Gangways are timbered with three-piece sets and are lagged, but where the roof is unusually good, posts are used on the upper side with lagging back of them.

A heavy, brittle roof or a heaving floor sometimes makes it ultimately cheaper to drive a rock gangway in the underlying material at a distance of about 20 feet from the coal bed, though the first cost is greater. This method is also used in crossing zones producing an unusual amount of gas.

The folded and faulted condition of this area makes it necessary to drive an unusual amount of rock work. In solid rock these tunnels are not timbered as a rule, but in areas that have been disturbed by faults it is necessary to timber securely. In former years hand work was used exclusively in tunnel driving, but in recent years air drills have almost entirely replaced it. Various types of drills have been used, the water-Leyner type giving the best results in heavy work and the Jackhamer in light work.

At one mine the greatest distance driven in any one month was 90 feet. The tunnel was 8 feet wide and 7 feet high. The average daily rate of advance was 1 foot per man and the cost $9.30 per foot. In another mine the rock gangways were driven 6 feet in the clear at the top, 7 feet wide at the rails, and 6 feet 6 inches high. One such gangway cost $28.75 per yard and another cost $26.75 per yard. Crosscuts 5 feet high and 4 feet wide driven from this rock gangway cost $15 per yard.

BREAST AND PILLAR SYSTEM.

The breast and pillar methods used in Pierce County mines are similar in general plan, differing in detail according to character of the roof and the amount of gas encountered. The following method may be considered fairly typical: The coal is 4 feet thick, with a parting of shale near the center, dips 51°, and has a main roof of sandstone and a cap rock 1 foot 6 inches thick. Six-foot chutes are driven from the gangway to the first counter 40 feet up the dip, continued narrow for the first 15 feet above the counter and then gradually widened to 25 feet. Six-foot crosscuts are driven at intervals of 50 feet.

A board chute 3 feet wide and the height of the seam is built up the center of each breast, and wings are constructed immediately below each crosscut and near the center of each block for the purpose of protecting men walking up the manway from falling coal or rock.

Each breast is timbered with five lines of props, set on 4-foot centers, with stringers parallel to the dip reaching across three props. Batteries are built in the coal chute at 50 or 60 foot intervals, especially where the dip of the bed is sharp, in order to retard the progress of the coal and to prevent unnecessary breakage. The manway from the gangway to the first counter is built along the side of the coal chute. Two trapdoors are placed between the gangway and the first counter. In thin coal, where there is not room to slide a door upward, the door is hinged at the top so that it will fall into place when released.

The other methods of breast and pillar work used in this district depend on local conditions as to the amount of timbering necessary and the position of the coal chute. The method of pillar drawing, like the method of ventilation, is similar to that used in other counties and has been described.

SPECIAL BREAST AND PILLAR SYSTEM.

At one of the mines an unusual amount of gas was found in two of the levels. (See Fig. 21.) Outbursts of gas occurred while miners were working in the solid coal, and, as indicated in the drawing, two outbursts had fatal results. On December 5, 1917, the coal was forced out of the solid for a distance of 40 or 50 feet, and about 50 tons of coal was forced into the crosscut. In the part of the bed in which this outburst occurred the coal was more or less crushed, with numerous slips close together and parallel to each other, and nearly parallel to the strike of the gassy zone that apparently crosses this field. The broken condition of the coal indicated a movement along this zone and suggested that the presence of the large amount of gas was due to chemical changes.

A method of working adopted with the idea of draining off this gas so that crosscuts could be driven in the solid coal is illustrated in Figure 22. The position of the gangway was changed from the coal bed to the rock underlying the bed at a stratigraphic distance of 20 feet. Another effort was made to drain the gas from this zone by driving a pair of chutes, as shown in Figure 22, up to the level above and connecting with an airway at the surface. The driving of rock gangways and rock chutes, however, had little or no effect. The work in this mine has been stopped temporarily, and an effort is being made closer to the surface to determine the reason for the existence of the gassy belt.

With this system of operation, ventilation is simple and the intake and return airways are always well preserved and form permanent passageways for the men to get out of the mine in an accident. The upper gangways also are kept open and are useful for bringing timber into the upper working places.

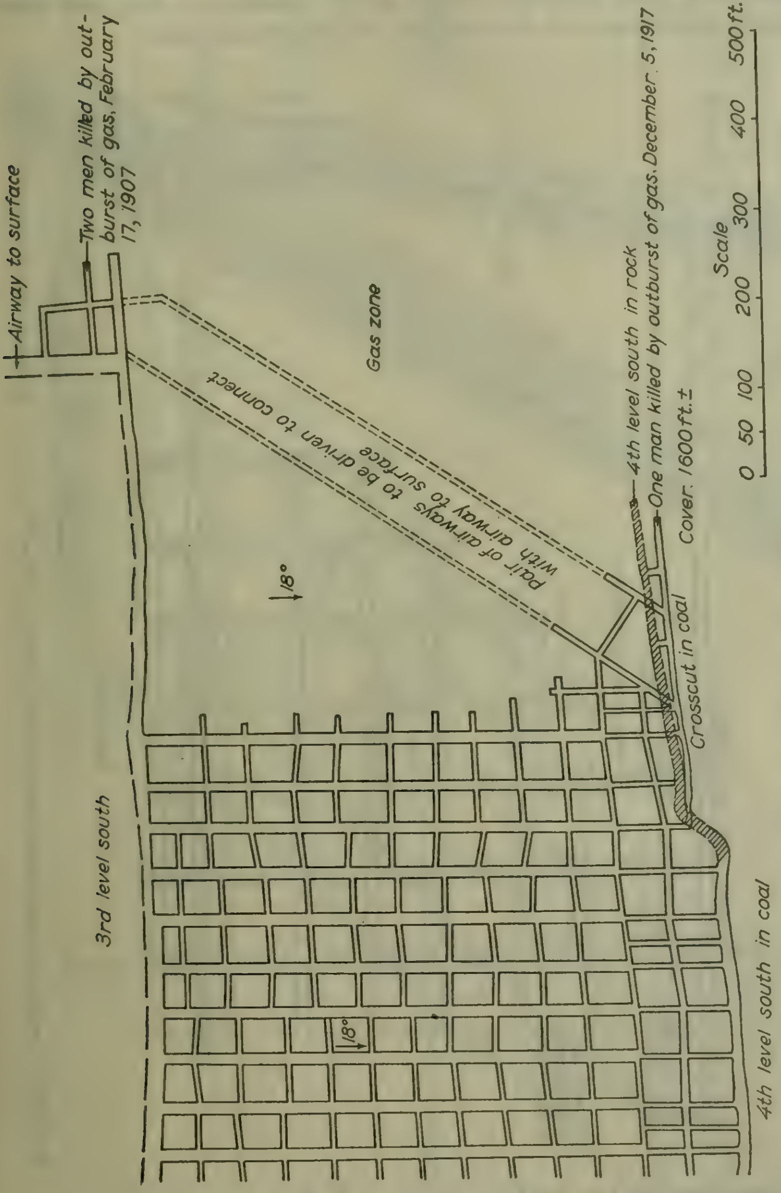

Airway to surface
Two men killed by outburst of gas, February 17, 1907
Gas zone
Pair of airways to be driven to connect with airway to surface
18°
4th level south in rock
One man killed by outburst of gas. December 5, 1917
Cover 1600 ft.±
Crosscut in coal
Scale
0 50 100 200 300 400 500 ft.
3rd level south
18°
4th level south in coal

FIGURE 21.—Location of gas outbursts in Wingate mine; also method of rearranging workings to avoid outbursts.

CHUTE AND PILLAR SYSTEM.

Where the character of the inclosing walls is such that large working places can not be kept open without too much timbering, the chute and pillar system is used. Chutes are generally driven at 40 to 60 foot intervals, on the full pitch of the bed, with crosscuts every 50 or 60 feet. The ordinary system of chute and pillar mining has already been described under Lewis County (p. 13), and only special applications of the method will be covered here.

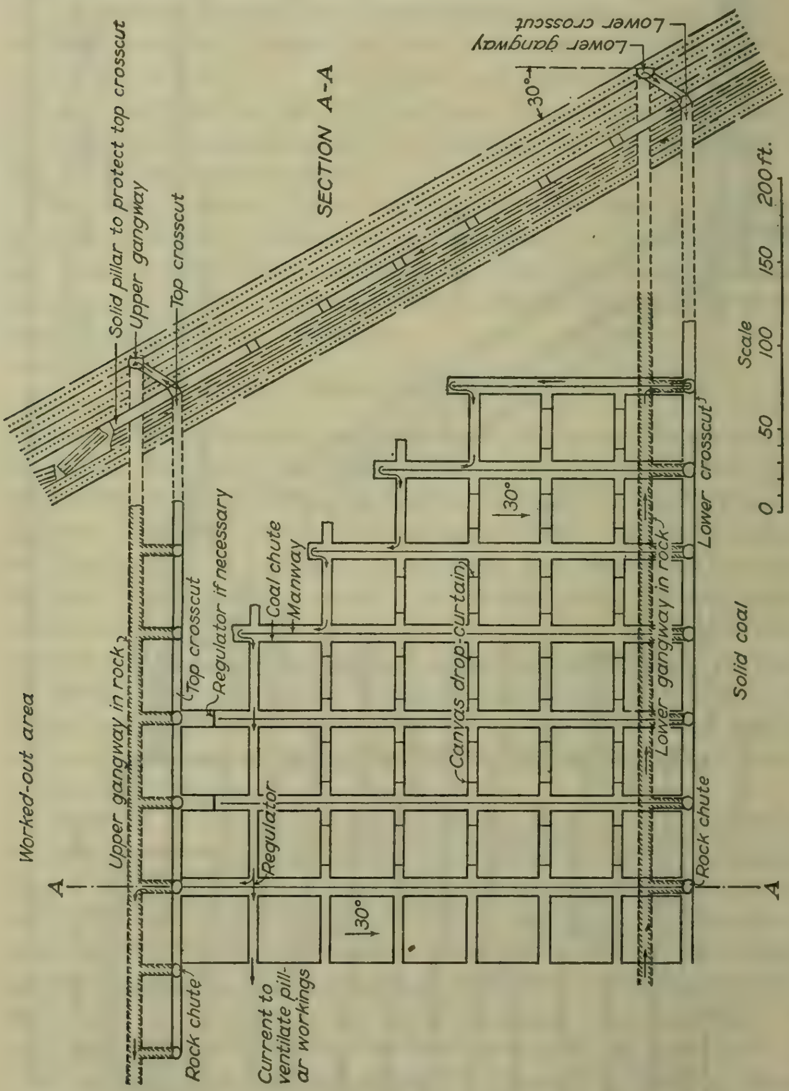


FIGURE 22.—Ineffective method of working with rock gangway and rock chutes tried in gaseous district, Carbonado mine.

At one place in the Wilkeson mine, a bed 11 feet thick dips 80°; the roof is brittle and caves when openings of considerable size are mined out. To meet this condition, the method shown in Figure 23 has been developed. The gangway is driven in the coal bed and se-

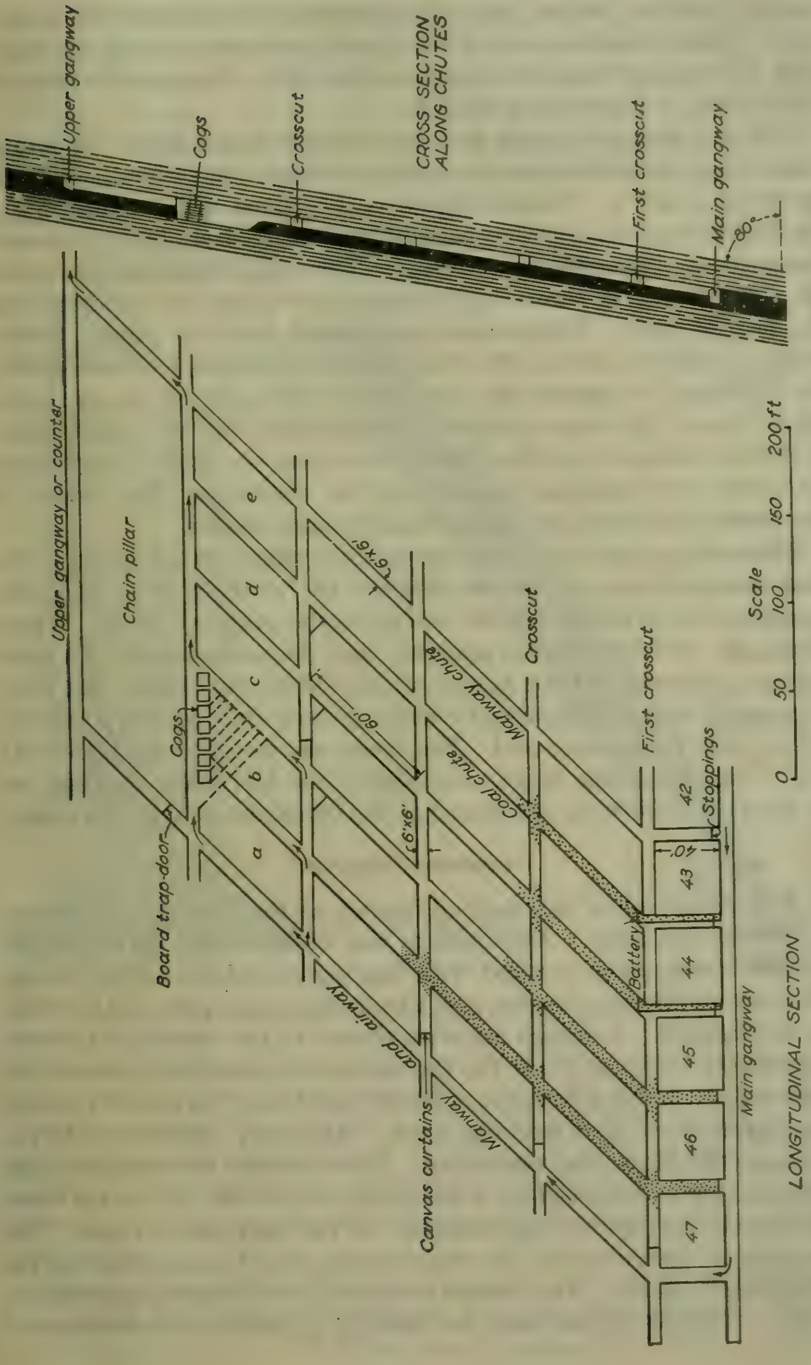


FIGURE 23.—Chute and pillar system used in working 11-foot coal bed with dip of 80°, Wilkeson mine.

curely timbered. Six-foot chutes are driven on 50-foot centers up the full pitch of the bed to the first counter, 40 feet above the gangway. Above the first counter the chutes are driven at such an angle that the slope of the chute itself is about 50°. Horizontal crosscuts are driven at intervals of 60 feet.

When a series of chutes have reached the pillar below the gangway above, preparations are made to remove the pillars, as shown in blocks *a* and *b*. First, a skip of coal is taken from along the top of the block; and a series of cogs 7 by 7 feet, securely built, is placed immediately below the top crosscut. Then diagonal skips are taken along the block, as shown by the dotted lines, and the coal goes into the nearest chute. This process is continued down the pillar. Sometimes a pillar of coal is left at the upper right corner of each block, as indicated, to support the cogs when a fall of roof occurs in the upper area. The upper gangway is kept open, and every sixth chute is driven through the pillar below it to serve as a return airway and as a means of bringing timber into the workings. The timber is dropped down the chute and is distributed as needed.

The main gangway is the intake in this system, the air going to the last crosscut, then up the last chute to the working face, along the working face to the first chute, and up to the gangway above. Trapdoors are used between the gangway and the first counter. In some mines a manway is built along the side of the coal chute, but more frequently every fifth or sixth chute is used as a manway and the others only for passing coal. The chutes are usually kept filled with coal, thus preventing short-circuiting of the air; when they are not so filled, drop curtains are placed in the crosscuts between the chutes.

"BOOMING" SYSTEM.

A modification of this method, known as the "booming" system, is used at one mine. After chutes and crosscuts are driven as described above, props covered with lagging are placed along the upper part of the top counter and along the upper part of the block to be removed. Batteries are then placed in the chutes at the bottom of the block and coal for the miners to stand on is allowed to accumulate on these batteries, enough coal being drawn off through the batteries to give working room. Auxiliary chutes are driven through the blocks for ventilation. This method is considered safe for working a thick bed on a steep dip, as the men are at all times protected from any caving material in the area above them. The amount of timber used is less than one-third of that required in the "cogging" system. Two miners can load 75 to 125 cars daily from a pillar. Powder is used only for starting a block at the batteries.

LONGWALL METHOD.

In the Miller bed at the Carbonado mine, where the character of the roof made the cost of mining by chute or breast methods prohibitive, a longwall system has been used. (See Figs. 24 and 25.) The bed averages 4 feet 5 inches in thickness between walls, has an immediate roof of carbonaceous shale and bone 4 feet thick, and a main roof of brittle shale for at least 4 feet above the first roof. The dip is 25 to 35° in this part of the mine.

A rock gangway is driven at a stratigraphic distance of 20 feet below the bed, and at intervals of 32 feet rock chutes are driven to the coal with 10-foot chutes driven up the pitch from the ends of the rock chutes, the latter being widened to form triangular connections with the working face. When a longwall face is to be opened, a pair of chutes 10 feet wide and 12 feet apart, with crosscuts every 60 feet, are first started on the full pitch of the bed. One of these connects with the rock crosscut leading to the rock gangway of the level above.

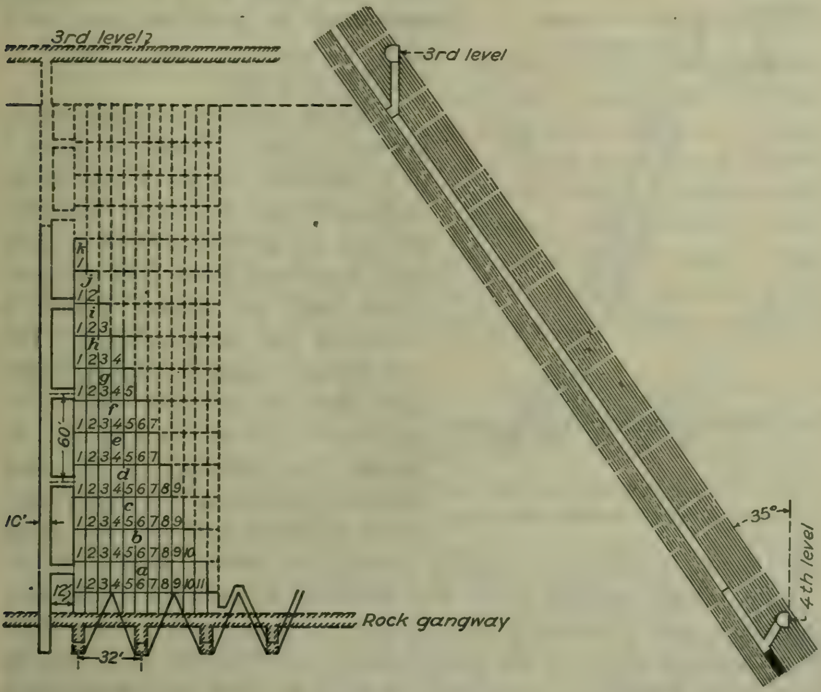


FIGURE 24.—Opening out a longwall face in a coal bed dipping 35°.

When the chute from which the longwall face is to be started has been driven the length of one block, a face is started from its side, as for instance at 1*a*. When the miner working this chute has proceeded the length of another step, another longwall face is started as at 1*b*, and at the same time the man on the lower face begins work on skip 2*a*, and so on. The longwall face is shown in solid lines in Figure 24, and at the time indicated the chute had been driven up to 1*a* and the miner on the lower block was working at 11*a*.

The longwall face, after it has been thoroughly opened, is shown in Figure 25. The coal chute which parallels the longwall face is kept about 12 feet from the face, and at regular intervals short wings are built from the working face to the chute to deflect the coal. The skip is kept at a uniform width of 6 feet, but the length up the pitch may vary from 18 to 40 feet. It is customary to have one man to a skip; his contract rate is based on a width of 6 feet.

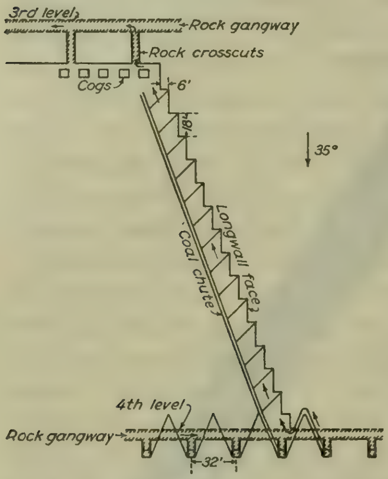


FIGURE 25.—Longwall face in coal bed dipping 35°. Carbonado mine.

A fairly uniform system of timbering is used. Posts of 6 by 6 inch material are set 4 feet apart and sunk into the solid footwall. On top of these are 6 by 6 inch caps spanning from post to post. These sets are placed within 6 inches of the working face. The coal chute is made by laying a concave sheet of 30-inch sheet iron against the side of the lagging. To protect the openings to the rock crosscut connecting the upper part of the longwall face with the gangway above, a series of cogs is placed, as shown in Figure 25.

Joint planes parallel to the dip occurred in the roof of the bed, and there was a tendency for the roof to break along these lines. Experience showed that the roof pressure could be best controlled by keeping the longwall face as nearly at an angle of 45° across the pitch as was practicable, keeping in mind the grade necessary to make coal slide down the chute. The roof was supported better in this way than if the face of the workings had been more nearly parallel to the pitch. Timber is brought from the outside to the rock tunnel in the level above, and then is passed through the nearest crosscut to the top of the longwall face, where it is distributed as needed. Ventilation is very simple, as Figure 25 indicates. The air enters through the lower rock gangway, then passes up along the longwall face to the rock crosscut which connects with the upper gangway.

BLASTING.

No mining machines are used in this district. Much of the coal is shot from the solid, especially in those beds where no special effort is made to produce coal for domestic use. Where domestic coal is desired, pick mining is practiced in some places. In 1917, 52.39 per cent was mined by hand and 37.61 per cent was shot off the solid. The explosives used were dynamite, 86.4 per cent, and permissible, 13.6 per cent.

PREPARATION.

Practically all the coal mined in Pierce County is cleaned at the surface.

TIMBERING.

This district as a whole probably requires more timber per ton of coal produced than any other in the United States. Much timber is required for chutes and for supports to maintain them, and many beds have inclosing walls that require a large quantity of timber. The timber in Pierce County is an original stand and hence somewhat different from that in King County, where there is much second-growth timber. In Pierce County most of the timber is first growth—Douglas fir, spruce, and hemlock. Nearly all mine props and laggings are made of split fir, and gangway timbers usually of second-growth fir.

In many mines counter gangways—usually provided with rails and timber trucks—are kept open above the level being worked, so that mine timber can be taken readily to the working faces. From the truck the timber is dropped down through timber chutes. In a mine where it is impracticable to maintain a counter gangway the timber is sent down the slope and along the gangway to the bottom of a chute having a comparatively smooth bottom, a truck with four low wheels without flanges being used to haul the timber. The truck is hauled up the pitch by the haulage motor, a rope from the truck being passed through a sheave at the top of the chute and then down to the haulage motor on the gangway.

MINE FIRES.

No mines in Pierce County are subject to fires from spontaneous combustion. Fires have occurred, but they have been started by ignition of the timber or other combustible material.

VENTILATION.

In mines where steam locomotives are not used the slope and main haulageway form the intake. Where steam locomotives are used air chutes are usually driven to the surface as intakes and the air, after passing over the working faces, travels along the main haulageway to the fan. Two doors are placed between the entrance to the haulageway and the fan.

OVERCASTS.

Few overcasts are needed. They are usually built of wooden blocks and coated with cement.

STOPPINGS.

Main stoppings, between main and return airways, are sometimes built of wooden blocks when they are to be permanent, but double doors are used more frequently. In crosscuts between chutes or breasts, stoppings of loose coal are sometimes used, especially on heavy pitches; elsewhere wooden stoppings are used, and sometimes curtains are hung.

DOORS.

Self-closing wooden doors are used in most mines, though an automatic door at Wilkeson works well.

EASTERN WASHINGTON.

KITTITAS COUNTY.

The coals of Kittitas County occur in four places. The largest and by far the most important section is the Roslyn-Cle Elum district, which is 105 miles by rail from Seattle and 300 miles west of Spokane. On Taneum Creek about 8 miles west of Thorpe is a small area of coal land, and near the head of the creek is another small area in which thin beds of coal have been found. Another irregular area of coal-bearing formation lies near the headwaters of Manastash Creek. Figure 26 indicates these areas.

The Roslyn-Cle Elum field is very important on account of the character of the coals, the comparative ease of mining, and the favorable situation in relation to markets of eastern Washington, western Idaho, and northeastern Oregon. Coal has been produced on a commercial scale in this field since 1887, from the completion of the Northern Pacific Railway into the district in the autumn of 1886. Plate VII shows the Roslyn field and gives the location of mines.

From the study of fossil remains collected within the Roslyn formation, it has been determined that these coal beds are of Eocene age.[7]

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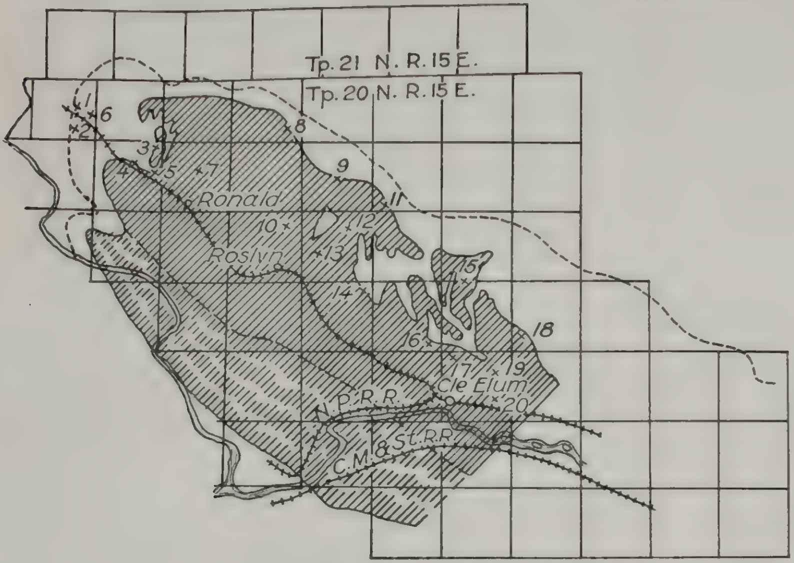
[7] Smith, G. O., Mount Stuart Folio 106, U. S. Geol. Survey, 1904.



No.	Name of mine.	Name of company.	No.	Name of mine.	Name of company.
1	Wright	Roslyn Fuel Co.	11		Yakima-Roslyn Coal Co.
2	Plant	Roslyn Coal & Coke Co.	12	No. 6	Northwestern Improvement Co.
3	Busy Bee	Do.	13	No. 1	Do.
4	Nos. 1 and 2	Roslyn Fuel Co.	14	No. 5	Do.
5	Patrick	Roslyn Cascade Coal Co.	15	Summit	Roslyn Fuel Co.
6	No. 3	Roslyn Fuel Co.	16	No. 7	Northwestern Improvement Co.
7	do	Northwestern Improvement Co.	17	Cle Elum No. 2	Do.
8	No. 8	Do.	18		Cle Elum Coal Co.
9	No. 2 Hillside	Do.	19	Cle Elum No. 1	Northwestern Improvement Co.
10	No. 2 Slope		20	Queen	Roslyn Fuel Co.

MAP OF ROSLYN COAL FIELD, SHOWING KNOWN AND PROBABLE EXTENT OF ROSLYN BED, ALSO LOCATION OF MINES. KNOWN EXTENT OF BED INDICATED BY CONTINUOUS LINES; PROBABLE EXTENT BY BROKEN LINES.

42456°—24. (Face p. 58.)

TOPOGRAPHY.

The topography of the Roslyn field is controlled largely by a stratum of massive sandstone which overlies the Roslyn bed. Along the northeastern limits of the field, where the drainage is into the Teanaway Basin, the hillsides are rather steep. From the edge of this bluff the beds dip southwesterly at an average angle of about 10° and the surface conforms to this dip.

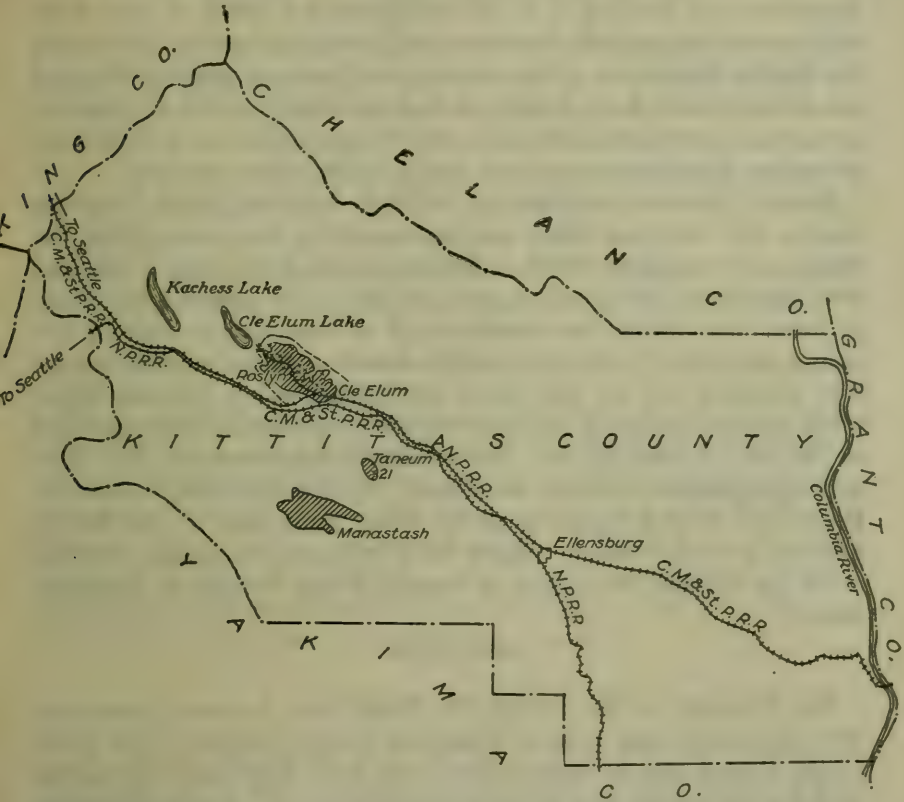


Figure 26.—Map of Kittitas County, showing Roslyn-Cle Elum, Taneum, and Manastash coal fields and transportation lines.

At the level of the railroad, which extends from northwest to southeast along the middle of the field, the surface becomes flatter and has been subjected to modification by erosion and by deposition of river gravels. This condition exists until the Cle Elum River is reached, at the western margin of the field, where the contact between the Teanaway basalt and the Roslyn formation occurs. From this point to the west and northwest rugged hills of igneous rock modified by erosion are the predominating feature. The elevations in the field range from 1,900 feet above sea level at Cle Elum to 3,700 feet along the eastern margin of the coal area.

STRATIGRAPHY.

The Roslyn formation, in which the coal occurs, has a thickness of approximately 3,500 feet, the upper 1,200 feet of which has been penetrated by drill holes in the Roslyn field. Underlying the Roslyn formation and limiting it on the southwest is a series of lava flows with accompanying tuffs known as the Teanaway basalts. Overlying the Roslyn formation at the extreme southeastern part of the field is a series of lava flows, known as Yakima basalt, which in places is more than 5,000 feet thick, and extends generally over a large part of eastern Washington and over parts of Idaho and Oregon.

Most of the coal produced in this field has been taken from the Roslyn bed, but four other coal beds occur in the strata above the Roslyn and two others below it, besides several beds of bony coal and bone that have been listed in drill records. It is possible that some of these beds, which are considered of no commercial value at the points penetrated by the drill, will be found workable at other points. Two hundred and ten feet above the Roslyn bed is the Big Seam, which has been mined in the western part of the field at Beekman, and at the No. 3 mine of the Northwestern Improvement Co. Two underlying seams have been developed. No. 6 bed is being worked by the Roslyn Coal & Coke Co. at the Plant mine, and by the Roslyn Fuel Co. at its No. 3 mine. Below No. 6 bed is that sometimes referred to as the Wright bed, which is opened at the Wright or Lakedale mine.

STRUCTURE.

The structure of the Roslyn-Cle Elum field is simple compared with that in the coal areas of King and Pierce Counties. The strike of the Roslyn bed is northwesterly, the beds dipping to the southwest for the greater part at an angle of about 10°. Along the southwestern margin of the field the Roslyn bed is compressed into three well-defined folds—two synclines and one anticline.

OUTPUT FROM ROSLYN BED.

The coal of the Roslyn bed—from which most of the output of the field thus far has been taken—is a true bituminous coal in the western part of the field, becoming a high grade subbituminous coal near Cle Elum. Coal from the western end of the field in the mine of the Roslyn Fuel Co. has been used for making gas, as well as for generating steam and for domestic purposes. The known workable tonnage of the Roslyn bed is insufficient to supply, indefinitely, the probable future demand and it may be necessary to work more extensively the Big Seam and beds underlying the Roslyn. The boundaries of the field are approximately known on the west, northwest, and northeast, but there is possibility of new discoveries to the southeast and southwest of the field as now outlined.

GENERAL CONDITIONS IN KITTITAS COUNTY.

Most of the coal mined in this district comes from the Roslyn bed. In hill workings, where the bed extends up the hillside above the valleys that furnish railroad routes, drifts have been driven on the strike of the bed from the outcrop. Where the coal is mined below the valley levels, slopes have been sunk, either on the full dip of the bed or at an angle with the dip. Gangways or entries have been turned from these slopes at intervals of 300 to 500 feet. It has been necessary sometimes to drive rock slopes from the surface to the coal and to drive slopes on the coal from the point of intersection.

SURFACE HAULAGE.

Much coal is produced from the Roslyn bed at points above the railroads and is hauled for considerable distances on the surface. These surface roads in places consist of graded roadbeds, at other points they occupy tunnels, and in places they are supported by long trestles. One tramway has a total length of 10,000 feet. Such surface hauling increases greatly the cost of opening mines. The hoisting engine is sometimes used to drop the loaded cars from the mine mouth to the tipple and to haul back the empties.

MINING METHODS.

The Roslyn bed averages a trifle less than 4½ feet in thickness. It is overlain by a bed of shale, or cap rock, varying from about 3 inches to nearly 2 feet in thickness. On account of thinness of the bed and presence of the cap rock, which easily falls, it was thought in the earlier days of operation that the longwall system could be applied successfully, but experience showed that better results are obtained with room and pillar methods.

As mining is now carried on the cap rock is taken down and gobbed when it is less than 1 foot thick and is friable, but where it is more than 1 foot thick an attempt is made to hold it. Other impurities of the bed, which sometimes occur in rather large quantities, are removed by the miners and gobbed. There is nowhere pitch

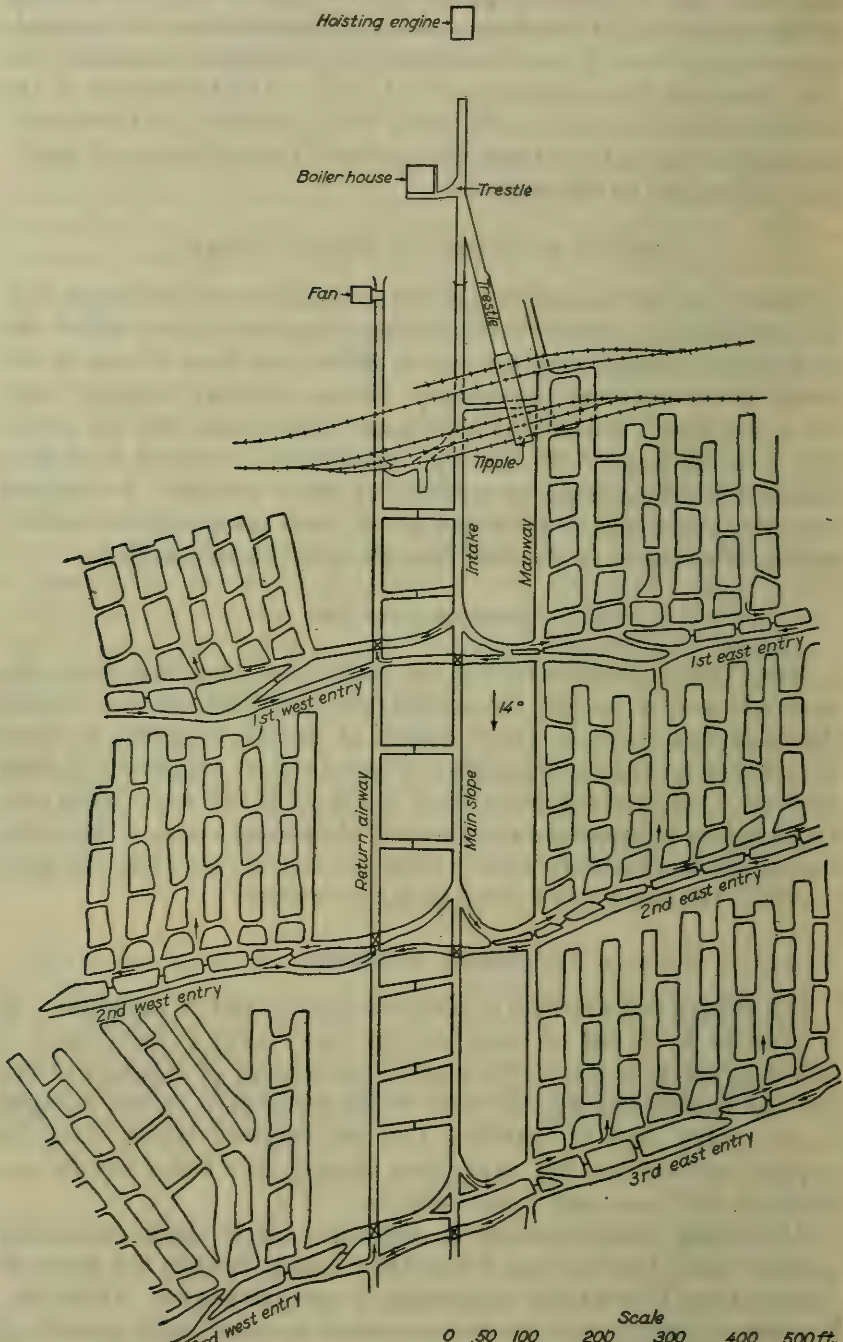


FIGURE 27.—One method of working Roslyn bed in Roslyn field; also arrangement of surface buildings.

enough to make impossible the separation of impurities underground. The coal breaks in rather large lumps and has a bright, clean surface; therefore it finds a ready market in competition with other coals of less pleasing appearance. The smaller sizes are washed and are readily sold in the steam and gas coal markets.

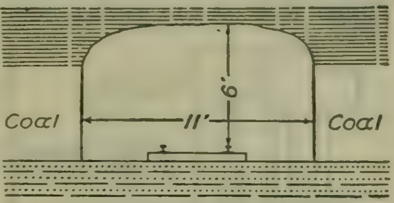


FIGURE 28.—Dimensions of single slope, Roslyn bed, Roslyn field.

The general plan of operation in this field is shown in Figure 27. The slope is usually sunk on the full dip of the bed. Parallel to the slope and separated from it by a pillar about 100 feet wide is the return airway. Crosscuts are driven every 50 or 60 feet. Figure 28 shows the dimensions of slopes as ordinarily driven and also indicates that single tracks are used.

GANGWAYS OR ENTRIES.

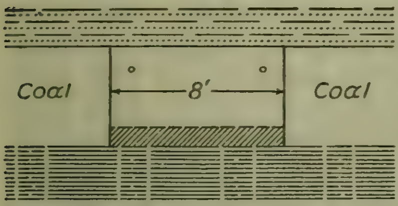


FIGURE 29.—One method of driving gangway or entry, Roslyn bed, Roslyn field.

Gangways or entries are turned from the main slope at intervals of 300 to 500 feet. These entries are from 8 to 11 feet wide and are driven to the height of the coal seam. The method of driving them is shown in Figures 29 and 30. Two or two and one-half sticks of a permissible explosive are placed in each hole, which is then tamped with clay. The shots are fired by shot firers at the close of the shift. Safety fuses are used when gas is present.

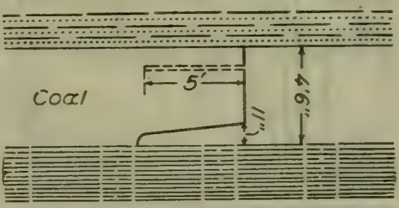


FIGURE 30.—One method of holing-in, in driving gangways or entries, Roslyn bed, Roslyn field.

It was formerly the custom to drive entries 16 feet wide and to use one side for gobbing the waste rock, leaving a clearance of 8 feet for haulage purposes.

Under the method now followed, the cap rock is removed from the mine when it is taken down. Return entries are driven parallel to the main entries or gangways, usually on the dip side, and separated from the main entries by 30-foot pillars. Crosscuts are driven every 50 or 60 feet. These back entries, or airways, are 8 feet wide. The coal is taken into the main entry through slants.

ROOMS.

In several mines wide rooms with double necks have been used, but better results are obtained with single rooms. The method of driving single rooms is shown in Figure 31. The necks are made 8 feet wide at the entries and are gradually widened to 12 feet at the first crosscut, 20 feet from entry. From the inby end of this crosscut the room is driven at its full width, usually 20 feet.

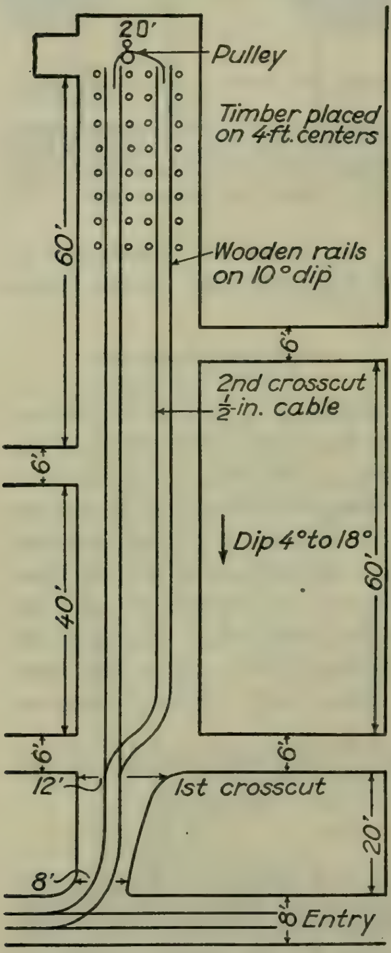


FIGURE 31.—One method of mining rooms, using cars to face.

One method of laying tracks and timbering rooms in the Big Bed is illustrated in Figure 31, which shows four lines of props set on four-foot centers. Another method of setting props in four lines is to place one line 18 inches from the rib; one line between the tracks, and two lines between the tracks and the other rib, the wide space betwen the rib and the track being used for storing refuse. Crosscuts 6 feet wide are driven between rooms at intervals of 60 feet.

The method of handling cars in the rooms depends on the dip of the bed. Where the dip ranges from 0° to 4° the cars are pushed directly to the face, but where the dip is from 4° to 18°, ropes and sheaves—or "McGinties"—are used, the descending loaded car pulling up the empty. Figure 31 illustrates the arrangement of the tracks, and Figure 32 gives the details of the sheave and its fastening.

When the dip of the bed is more than about 18° sheet-iron chutes are built along one rib and wing chutes direct the coal from the other side of the working face to the chute, Figure 33. Four lines of props are set on 4-foot centers. The air is carried to the working face by means of a brattice cloth fastened to the props. The best results are obtained by carrying the face in a direction diagonal to the dip of the bed, the work being easy and little powder being required. The coal is undercut for a depth of 3 feet, and one small shot is placed in the upper left-hand corner of the room.

CUTTING THE COAL AND SHOT FIRING.

Most of the coal produced in this county is mined with picks. Post punchers have been tried, but they are less satisfactory than hand work. In 1917 only 0.33 per cent of the total coal mined was undercut by machines, 77.86 per cent was mined by hand, and 21.81 per cent was shot off the solid. The explosives used were: 56.2 per cent black powder, 1.8 per cent dynamite, and 42 per cent permissibles. When the coal is cut with picks before shooting the mining is made in either the top or bottom of the bed and the coal is shot down or up, as seems preferable. When the coal is shot off the solid from five to six holes are usually placed in the face, bored 5 or 6 feet in depth.

Since gas is found in some mines, precautions are taken to avoid explosions from shot firing. The shot firer first examines the place for gas; if gas is found, he takes steps for its removal. As a further precaution he then lights the fuse from a glowing wick instead of a flame—obtaining this by extinguishing his safety lamp, placing a bit

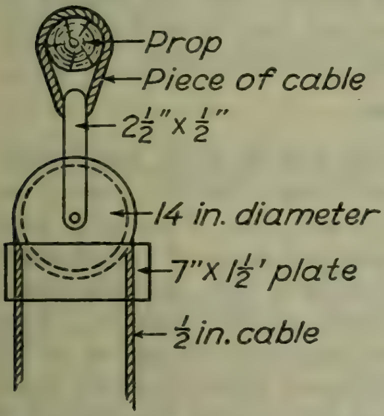


FIGURE 32.—Detail of sheave, or "McGinty," and its fastenings.

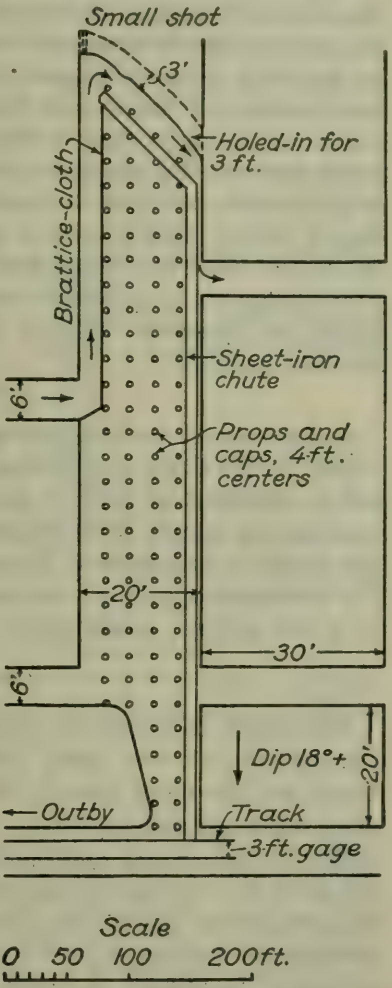


FIGURE 33.—Method of driving chute room in Roslyn field.

of wick inside, relighting the lamp to ignite this wick and, after he has again extinguished the lamp, removing the glowing wick, which he uses as a match. No serious accidents have occurred under this method of shooting.

PILLAR DRAWING.

In general, entries and rooms are worked out to the boundary. Room pillars are then drawn back to the entry block or stumps, and the entry pillar is next removed. Slope pillars are removed last. In the chute rooms a diagonal skip is first taken off the upper left-hand corner of the second block above the gangway (first block above the stumps), then a skip about 6 feet wide is taken off the pillar between this point and the end of the room. After the first skip is taken the chute is moved close to the new rib and another skip is taken. This process is repeated until the entire pillar above the second block has been taken off, these two blocks being left next to the gangway to protect it until it is finally abandoned, when the blocks are removed. The cap rock caves in the room as the pillar drawing proceeds.

TIMBERING.

In parts of the bed that are undisturbed it is not customary to use timber in the slopes and entries, but where the roof is friable or the bed is disturbed by rolls or pinches timbering is necessary. When possible the simple form of prop and cap is employed, but where the weight is considerable three-piece sets are used, with lagging on the sides and top. In the rooms props and caps are used, commonly on 4-foot centers. Little effort is made to recover timber.

HAULAGE.

The tracks in slopes are usually laid with 30 or 40 pound rails; the ties are set 2 feet apart, are 1½ feet longer than the gage of the track, and are made usually of 5 by 7 inch pine. Ordinarily these slope tracks are not ballasted. In entries and rooms 16 and 20 pound rails are used. Track gages are either 30 or 36 inch. Electric motors are used for hauling, though some mules are still employed. Some storage-battery locomotives have been introduced to replace trolley locomotives because of their independence of trolley wire, the elimination of the danger of shock, and, in gassy mines, the removal of the danger of explosion. For surface haulage electric locomotives are used wherever the inclination of the road permits; on the inclines cables are used. Because of heavy snowfall in winter, snow sheds are built to protect the roads, especially along the cuts.

VENTILATION.

The mines above drainage level in the hillsides are usually free from gas, but below water level gas is encountered in increasing quantities as greater depths are reached.

The mines are all well ventilated with mechanically driven fans. The main slope is usually the intake, and the air is split at each level. In nearly all cases exhaust fans are used, but many of them could be converted readily into blowing fans. In addition to the fans on the surface, booster fans are used underground. Figure 9 (p. 25) illustrates the common method of ventilation and shows that few doors are used. It shows also the position of overcasts.

In crosscuts between main and return entries concrete stoppings 4 inches thick are used; details of their construction are shown in Figure 34. Between rooms, board or rock stoppings or canvas curtains are used. Concrete is used for overcasts in some mines and 2-foot wooden blocks in others. When wooden blocks are used, both faces of the blocks are cemented. The top of the overcast is covered with 8 by 10 inch timber, fireproofed with a coating of cement. When concrete is used, the sides are made 9 inches thick and the top is constructed of 30-pound rails with 6 inches of concrete between rails. The latter type has proved entirely satisfactory. Few doors are necessary, and the air current is usually deflected into rooms by drop curtains of canvas. When doors are needed they are made of wood.

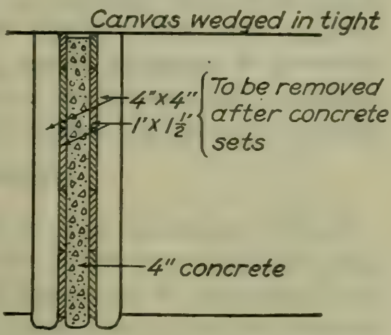


FIGURE 34.—Detail of concrete stopping and crosscuts between entries.

LIGHTING.

The slope and parts of the main haulageways, as well as all pump rooms in the larger mines, are lighted by electricity. In the hill workings above water level where no gas is found, open carbide lamps are used. Below water level, gas enough is found to make necessary the exclusive use of safety lamps. The electric cap lamp is gradually replacing the flame safety lamp.

COSTS.

PRODUCTION.

The cost of producing coal in Washington is high, owing to physical conditions largely. The preceding discussion has noted the cover of glacial material, the faults, folds, and igneous intrusions, the depletion of the better beds, the extensive timbering required, the long hauls, and the necessity of cleaning the coal. Not only is the cost of prospecting high on account of glacial material that must be penetrated—a layer that in many parts of King and Pierce Counties is more than 200 feet thick—but the frequent faults and sharp folds encountered in some districts entail heavy expense for prospecting. Many thousands of dollars have been spent with unsatisfactory results in attempting to find well-known coal beds beyond faulted zones.

Affected by the factors mentioned above, the cost of producing coal after it has been prospected is growing. In the early history of coal mining in Washington, there was a large tonnage of coal above the general water level; but as the readily available beds became depleted, it became necessary to drive slopes or sink shafts to win the coal from lower levels. With increasing depth the cost of timbering is increased, larger quantities of gas are sometimes encountered, and ventilation is consequently more extensive. Some mines become dry and require sprinkling systems.

PREPARATION.

Another important item of cost is preparation of the coal. In early days beds were mined that did not require much preparation, like the McKay, Wingate, and Roslyn. As these beds approach exhaustion, however, beds must be worked that have numerous bands of impurities, as well as good coal. The larger sizes can be cleaned by hand picking, but cleaning the smaller sizes requires washing plants. In addition, wages have increased and the output per man has decreased. The following tables of wages and of output per man are based on reports of the State mine inspector. The decrease in the efficiency of workmen may be attributed in part to the fact that in 1918, when the production per man was low, the mines generally were worked steadily, whereas in 1915—the year showing the highest output per man—many miners were working half time or less. The labor turnover, moreover, was greater in 1918, as many skilled miners left the mines for military service and for work in shipbuilding and other industries.

The following digest of costs is based upon reports furnished to the Federal Trade Commission. These records do not represent costs of individual mines or companies, but are compiled to show average costs for different districts. The figures given are weighted averages obtained by assuming the cost of each company to be the same proportion of the total cost of a district as the output of the company is of the total output of the district. For example, in Kittitas County the total tonnage for which cost figures were supplied was 1,671,790 tons. Of this amount the Roslyn Fuel Co. produced 15.2 per cent. It was then assumed that the several cost items of that company should be figured as 15.2 per cent of the total cost for the same items for all mines of which costs were reported. These figures cover the entire year 1918.

The following districts are considered: Lewis County, subbituminous; Kittitas County and King County, subbituminous; King County, bituminous; Pierce County, coking bituminous. Thurston County was not included, because costs were supplied for only one mine.

LEWIS COUNTY.

SUBBITUMINOUS DISTRICT.

Costs for three mines were supplied. Total tonnage represented is 89,135 tons, of which one mine produced 73.6 per cent.

Average costs per ton for subbituminous mines.

Labor	$1.899
Supplies	.400
Fixed charges	.455
Average total	2.754
Lowest	2.620
Highest	3.600

KITTITAS COUNTY.

SUBBITUMINOUS DISTRICT.

The following figures are computed from costs at all the mines of the Northwestern Improvement Co., the Roslyn Fuel Co., the Independent Coal & Coke Co., and the Roslyn Cascade Coal Co. These figures cover the cost of production of 1,671,790 tons, of which the Northwestern Improvement Co. produced 71.5 per cent.

Average costs per ton for subbituminous mines.

Labor	$1.830
Supplies	.274
Fixed charges	.417
Average total	2.521
Lowest	2.330
Highest	2.923

Some items of cost are as follows:

LABOR.

Mining, $1.132 to $1.34; yardage and dead work, $0.160 to $0.164; haulage, $0.186 to $0.202; tipple, $0.044 to $0.061; power, $0.065 to $0.081; other operating labor, $0.119 to $0.236; superintendence and engineering, $0.035 to $0.072.

SUPPLIES.

Mine timbers, $0.031 to $0.065; feed and other supplies, $0.015 to $0.017; fuel for power house, $0.039 to $0.240; other operating supplies, $0.031 to $0.071.

FIXED CHARGES.

Depreciation, $0.020 to $0.080; taxes (except income and excess profits), $0.009 to $0.031. Insurance, general, $0.002 to $0.011; liability and workmen's compensation, $0.061 to $0.067; salaries and expenses, $0.008 to $0.010; clerical and office expenses, $0.019 to $0.024; miscellaneous, $0.017 to $0.027.

KING COUNTY.

SUBBITUMINOUS DISTRICT.

The figures are based on four mines which produced 550,590 tons, of which one mine produced 58 per cent.

Average costs per ton for subbituminous mines.

Labor	$2.482
Supplies	.613
Fixed charges	.443
Average total	3.538
Lowest	3.080
Highest	4.380

The following are some items of cost:

LABOR.

Mining, $0.876; yardage and dead work, $0.272; haulage, $0.268; tipple, $0.260; power, $0.106; washery, $0.027; maintenance and repairs, $0.146; superintendence and engineering, $0.068; miscellaneous labor, $0.299.

SUPPLIES.

Mine timbers, $0.141; power-house fuel, $0.296; power purchased, $0.026; washery supplies, including water, $0.001; other operating supplies, $0.144; maintenance and repairs, structures, $0.007; equipment, $0.104.

FIXED CHARGES AND GENERAL EXPENSES.

Depreciation, structures, $0.026, equipment, $0.084; development, $0.011; taxes (except income and excess profit), $0.014; insurance, general, $0.007; liability or workmen's compensation, $0.068; salaries and expenses, $0.018; clerical salaries and office expenses, $0.095.

BITUMINOUS DISTRICT.

The following figures are based on the costs of seven mines in the Green River district of King County and of one mine in Pierce County, the latter being included because it is operated by a company that operates also in the Green River district. The total tonnage was 739,460 tons, of which one company produced 59.1 per cent.

Average costs per ton for bituminous mines.

Labor	$2.726
Supplies	.677
Fixed charges	.722
Average total	4.125
Lowest	3.330
Highest	4.510

Some items of cost are as follows:

LABOR.

Mining and washery, $1.965 to $2.666; superintendence and engineering, $0.448 to $0.092.

SUPPLIES.

Operating and repairs, mining and washery, $0.301 to $0.314; power purchased, $0.107; depreciation and depletion, $0.325 to $0.566; taxes (except income and excess profits), $0.030; insurance, general, $0.026 to $0.029; liability and workmen's compensation, $0.067 to $0.082.

SALARIES AND GENERAL EXPENSE.

Officers' salaries and expenses, $0.068 to $0.110; clerical salaries and office expenses, $0.045 to $0.118; miscellaneous, $0.041 to $0.056; selling and delivery expenses, $0.036 to $0.297.

PIERCE COUNTY.

COKING BITUMINOUS COAL.

The following costs are computed from those of three mines with a total output of 351,242 tons:

Average costs per ton for coking bituminous coal mines.

Labor	$2.683
Supplies	.702
Fixed charges	.942
Average total	4.327
Lowest	4.165
Highest	5.145

Some details of cost are as follows:

LABOR.

Mining, $0.522 to $1.980; haulage, $0.341 to $0.438; tipple, $0.053 to $0.131; washery, $0.041 to $0.112; maintenance and repairs, structures, $0.004 to $0.093, equipment, $0.129 to $0.273; superintendence and engineering, $0.092 to $0.126.

SUPPLIES.

Mine timbers, $0.059 to $0.196; feed and other stable supplies, $0.012 to $0.052; power purchased, $0.068 to $0.122; maintenance and repairs, structures, $0.005 to $0.010, equipment, $0.077 to $0.096.

FIXED CHARGES.

Depreciation, structures, $0.060 to $0.214, equipment, $0.055 to $0.097; development, $0.041 to $0.043; taxes (except income and excess profits), $0.066 to $0.087; insurance, general, $0.007 to $0.049; insurance, liability or workmen's compensation, $0.080 to $0.132; officers' salaries and expenses, $0.046 to $0.095; miscellaneous and contingent, $0.165 to $0.197.

TABLES.

Tables 1–4, following, give data on wages and production in Washington coal fields:

TABLE 1.—*Scale of day wages paid in Washington coal mines.*[a]

Inside mine.	Day wage scale.			
	1914–15.	Sept. 1, 1916.	June 1, 1917.	Nov. 16, 1917.
Miners	$3.80	$3.95	$4.49	$5.89
Timbermen	3.80	3.95	4.49	5.89
Timbermen's helpers	3.15	3.30	3.80	5.20
Tracklayers	3.80	3.95	4.49	5.89
Tracklayers' helpers	3.15	3.30	3.80	5.80
Motormen	3.35	3.50	4.00	5.40
Drivers	3.35	3.50	4.00	5.40
Parting boys	1.90	2.00	2.50	3.50
Do	2.40	2.50	3.00	4.00
Greasers	1.85	1.95	2.45	3.45
Trappers	1.60	1.70	2.20	3.20
Rope riders	3.35	3.50	4.00	5.40
Locomotive engineers	3.40	3.50	4.00	5.40
Hoistmen on development work	3.15	3.30	3.80	5.20
Cagers	3.40	3.50	4.00	5.40
Cagers' helpers	3.15	3.30	3.80	5.20
Pump men	3.15	3.30	3.80	5.20
Inside labor not specified	3.15	3.30	3.80	5.20
Boys working on hoists, except on main slopes and auxiliary slopes	2.50	2.60	3.10	4.10

[a] In addition to increases in day wages, increases in contract prices occurred also.

TABLE 2.—*Scale of day wages paid in Washington coal mines.*[a]

Outside mine.	Day wage scale.			
	1914–15.	Sept. 1, 1916.	June 1, 1917.	Nov. 16, 1917.
Main hoisting engineers	$3.40	$3.75	$4.25	$5.65
Power-plant engineers	....	3.60	4.10	5.50
Compressor	....	3.55	4.05	5.45
Development	3.15	3.25	3.75	5.15
Electricians, first class, in and around mine	....	3.80	4.30	5.70
Electricians, second class, in and around mine	....	3.50	4.00	5.40
Machinists, first class, in and around mine	3.40	3.80	4.30	5.70
Machinists, second class, in and around mine	....	3.50	4.00	5.40
Electricians' and machinists' helpers, in and around mine	....	3.00	3.50	4.90
Firemen	3.00	3.15	3.65	5.05
Cagers	3.15	3.25	3.75	5.15
Cagers' helpers	2.75	3.85	3.35	4.75
Teamsters	2.90	3.00	3.50	4.90
Greasers	1.45	1.55	2.05	3.05
Couplers	1.60	1.70	2.20	3.20
Dumper, crossover	2.75	2.85	3.35	4.45
Blacksmiths, first class	3.70	3.80	4.30	5.70
Blacksmiths, second class	3.40	3.50	4.00	5.40
Blacksmiths' helpers	2.90	3.00	3.50	4.90
Carpenters, first class	3.70	3.80	4.30	5.70
Carpenters, second class	3.15	3.30	3.80	5.20
Car repairers	2.90	3.00	3.50	4.90
Choppers	2.90	3.00	3.50	4.90
Screeners, men	2.10	2.40	3.00	4.40
Screeners, boys	1.60	1.90	2.40	3.40
Moving picking table, men	2.20	2.40	3.00	4.40
Moving picking table, boys	1.70	1.90	2.40	3.40
Outside labor	2.60	2.75	3.25	4.65

[a] In addition to increases in day wages, there were increases in contract prices also.

TABLE 3.—*Number of tons per man a day for the coal-mining counties of Washington for the years 1913 to 1918.*

County.	1913	1914	1915	1916	1917	1918
Thurston	4.39	6.23	6.86	6.48	5.62	5.32
Kittitas	3.81	3.72	4.51	3.88	3.69	3.57
Lewis	2.95	2.65	4.16	3.89	3.12	2.93
King	2.36	2.23	2.91	2.59	2.42	2.22
Pierce	2.03	2.00	1.77	1.80	1.74	1.73

TABLE 4.—*Percentage of increase or decrease in output per man a day since 1915.*

County.	1914	1915	1916	1917	1918	Total decrease since 1915.
Thurston	+42.0	+10.0	−5.5	−13.2	−5.3	−24.0
Kittitas	−2.3	+2.0	−14.0	−4.9	−3.2	−22.1
Lewis	−10.0	+57.0	−6.5	−19.8	−6.1	−32.4
King	−5.5	+30.5	−11.0	−6.6	−8.3	−25.9
Pierce	−1.5	−11.5	+1.7	−3.3	−.57	−2.17

ACCIDENTS IN WASHINGTON COAL MINES.

The following tables, compiled from publications of the Bureau of Mines, show the accident record for the State of Washington. A wide variation appears in the number of accidents during the time covered, from 1903 to 1917; the lowest death rate was in 1905 and the highest in 1915. The accident causing the largest number of fatalities was the explosion in the Roslyn mine in 1892, at which 45 men were killed.

In consideration of the facts that the mines of Washington are becoming deeper, and at the same time drier and more gassy, the accident record is a favorable comment on the increasing care of mine workers and operators.

TABLE 5.—*Number of hours worked in and about coal mines in Washington and the fatality rate based on the number of 2,000-hour workers.*[a]

Year.	Days worked.	Total hours per day (all employees).	Total hours per year.	Number of 2,000-hour workers.	Fatalities.	
					Total.	Per 1,000 2,000-hour workers.
1903	285	44,751	12,754,035	6,377	25	3.92
1904	243	43,431	10,553,733	5,277	31	5.87
1905	227	39,594	8,987,838	4,494	12	2.67
1906	266	36,595	9,734,270	4,867	22	4.52
1907	273	47,911	13,079,703	6,540	37	5.66
1908	202	44,691	9,027,582	4,514	25	5.54
1909						
1910	256	50,697	12,978,432	6,489	43	6.63
1911	225	59,482	13,383,450	6,692	27	4.03
1912	226	44,377	10,029,202	5,014	14	2.79
1913	260	46,352	12,051,520	6,026	22	3.65
1914	191	46,528	8,886,848	4,443	17	3.83
1915	169	38,841	6,564,129	3,282	46	14.02
1916	217	38,380	8,328,460	4,164	21	5.04
1917	271	42,723	11,577,933	5,789	30	5.18
1918	275	40,911	11,250,525	5,625	33	5.87

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[a] Fay, A. H., Coal mine fatalities in the United States, 1870–1914, with statistics of coal production, labor, and mining methods, by States and calendar years: Bull. 115, Bureau of Mines, 1916, p. 334; Fay, A. H., Coal-mine fatalities in the United States, 1918, p. 32. Adams, W. W., Coal-mine fatalities in the United States, 1921: Tech. Paper 302, 1921, pp. 47–48.

TABLE 6.—*Number of hours to the working day, by years, in and about the coal mines in Washington.*[a]

Year.	8-hour day.		9-hour day.		10-hour day.		Men employed other than 8, 9, or 10 hours per day.	Total number of men employed.
	Number of mines.	Men employed.	Number of mines.	Men employed.	Number of mines.	Men employed.		
1903	5	342	17	2,245	6	2,180		4,768
1904	24	4,152	4	70			1,065	5,287
1905	18	3,644	1	28	8	353	740	4,765
1906	29	4,179	4	106	2	13	231	4,529
1907	41	5,594	1	5			346	5,945
1908	39	4,665	1	20			799	5,484
1909								5,992
1910	40	6,129					185	6,314
1911	45	5,642					1,594	7,236
1912	42	5,344			2	50	125	5,519
1913	52	5,794						5,794
1914	53	5,751			1	34	20	5,805
1915	52	4,809					41	4,850
1916	44	4,793					4	4,797
1917	47	5,085					227	5,312
1918	51	5,070					39	5,109
1919	45	5,022					14	5,036

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[a] Fay, A. H., Coal-mine fatalities in the United States, 1870–1914, with statistics of coal production, labor, and mining methods by States and calendar years: Bull. 115, Bureau of Mines, 1916, p. 334; Adams, W. W., Coal-mine fatalities in the United States, 1919: Bull. 196, Bureau of Mines, 1919, p. 50.

Adams, W. W., Coal-mine fatalities in the United States, 1922: Tech. Paper 339, Bureau of Mines, p. 47.

TABLE 7.—*Coal-mine accidents in Washington in which five or more men were killed.*[a]

Date.	Name of mine.	Location of mine.	Nature of Accident.	Number killed.
1892, May 10	Roslyn	Roslyn	Mine explosion	45
1894, Aug. 24	Franklin	Franklin	Mine fire	37
1895, Apr. 8	Blue Canyon	Lake Whatcom	Mine explosion	23
1899, Dec. 9	Carbon Hill No. 7	Carbonado	do	31
1900, Aug. 21	Issaquah No. 4	Issaquah	Smoke from burning air shaft	5
1902, Oct. 1	Lawson	Black Diamond	Mine explosion	11
1904, Dec. 7	No. 5	Burnett	do	17
1907, Apr. 26	Morgan	Black Diamond	do	7
1909, Oct. 3	Northwestern Imp. Co.	Roslyn	do	10
1910, Nov. 6	Lawson	Black Diamond	do	16
1915, Nov. 16	Northwestern Imp. Co.	Ravensdale	Coal-dust explosion	31
1917, Dec. 17	Wilkeson	Wilkeson	Inrush of water and gravel	5
1918, Aug. 28	Burnett	Burnett	Coal-dust explosion	12

[a] Fay, A. H., Coal-mine fatalities in the United States, 1870–1914, with statistics of coal production, labor, and mining methods, by States and calendar years: Bull. 115, Bureau of Mines, 1916, p. 333; Adams, W. W., Coal-mine fatalities in the United States, 1921: Tech. Paper 302, Bureau of Mines, 1922; p. 29.

TABLE 8.—*Fatalities due to the dip or pitch of coal seams in Washington mines, 1905 to 1917.*[a]

Cause of accident.	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Coal or rock sliding down pitch	3	1	4	2	1	1	2	2	1	1	2	....	[b] 7
Timber sliding down pitch	....	....	4	1	....	....	....	....	....	....	....	....	2
Runaway cars and men falling from cars or skips	2	7	3	5	1	3	5	....	3	3	1	1	1
Cars on haulage planes	....	2	....	....	....	....	1	....	1	....	....	1	....
Falling down slopes or chutes	....	....	....	1	2	2	3	3	....	....	....	1	3
Suffocated by gas outburst	....	1	....	....	2	....	....	....	....	....	....	....	3
Total	5	11	11	9	6	6	11	5	5	4	3	3	16
All fatalities	12	22	37	25	39	43	27	14	22	17	46	20	30

[a] Fay, A. H., Coal-mine fatalities in the United States, 1870–1914, with statistics of coal production, labor, and mining methods, by States and calendar years: Bull. 115, Bureau of Mines, 1916, p. 333.

[b] Includes disaster on December 17, 1917. Inrush of water and sand.

TABLE 9.—*Fatalities in Washington coal mines by principal causes during the years 1914 to 1917 and for the 29-year period 1889 to 1917.*[a]

Causes of accident.	1914	1915	1916	1917	Number killed, 1889–1917.		
					Total.	Per cent.	Per 1,000 employed.
Underground:							
Fall of roof and pillar, coal, rock, etc	8	8	7	6	211	28.44	1.69
Mine cars and locomotives	3	1	2	3	90	12.65	.72
Gas and dust explosions	1	31	2	......	229	30.47	1.83
Explosives	3	......	4	......	39	5.00	.31
Miscellaneous	1	3	3	18	127	15.94	1.02
Shaft	......	......	1	......	14	2.03	.11
Surface	1	3	2	3	44	5.47	.35
Total	17	46	21	30	754	100.00	6.03

[a] Fay, A. H., Coal-mine fatalities in the United States, 1919: Bull. 196, Bureau of Mines' p. 47: Adams, W. W., Coal-mine fatalities in the United States, 1921: Tech. Paper 302, Bureau of Mines, 1922, p. 42.

PUBLICATIONS ON COAL-MINING METHODS.

(*List does not include publications on electrical equipment, fires and explosions, explosives, legal regulations, mine gases, and sanitation.*)

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BULLETIN 60. Hydraulic mine filling, its use in the Pennsylvania anthracite fields, a preliminary report, by Charles Enzian. 1913. 77 pp., 3 pls., 12 figs.

BULLETIN 99. Mine ventilation stoppings, with especial reference to coal mines in Illinois, by R. Y. Williams. 1915. 30 pp., 4 pls., 4 figs.

BULLETIN 227. Flame safety lamps, by J. W. Paul, L. C. Ilsley, and E. J. Gleim. 1924. 212 pp.

TECHNICAL PAPER 1. The sampling of coal in the mine, by J. A. Holmes. 1911. 18 pp.

TECHNICAL PAPER 103. Organizing and conducting safety work in mines, by H. M. Wilson and J. R. Fleming. 1917. 57 pp., 35 figs.

TECHNICAL PAPER 154. Suggestions for improved methods of mining coal on Indian lands in Oklahoma, by J. J. Rutledge and Daniel Harrington. 1918. 35 pp., 8 pls., 4 figs.

TECHNICAL PAPER 237. Safe practice in using wire ropes in mines, by O. P. Hood and R. H. Kudlich. 1919. 9 pp.

MINERS' CIRCULAR 9. Accidents from falls of roof and coal, by G. S. Rice. 1912. 16 pp.

MINERS' CIRCULAR 11. Accidents from mine cars and locomotives, by L. M. Jones. 1912. 16 pp.

MINERS' CIRCULAR 18. Notes on miners' carbide lamps, by J. W. Paul. 1915. 11 pp.

INDEX.

A.
Page.
Accidents in mines, data on 75
Adams, W. W., work cited 74
Anthracite coal, location of, map showing 2
B.
Bagley, James, acknowledgments to 2
Bayne series, coal beds of 19
Bellingham mine, Whatcom County, mining at 15
Bituminous coal, in King County, quality of 22
Bituminous coals in State, location of, map showing 2
  reserves in State 1
Black Diamond mine, King County, mining at 20
Blasting methods in Lewis County 14
  in Pierce County 57
  in Roslyn field 65
  in Tono mine 8
Blue Canyon mine, Whatcom County, coal from 15
"Booming" system of chute and pillar mining, use of, in Pierce County 54
Botting, D. C., acknowledgments to 3
Breasts, wide, mining of 31
  figure showing 32
Breast and pillar system in King County 28–30
  figures showing 29, 31, 33
  in Pierce County 49–51
  figure showing 51
"Bumps" in King County mines, occurrence of 32
Burnett, coal beds at, relations of, figure showing 48
Burnett formation, Carbon River field, coal beds in 44
Burnett series, Pierce County, coal beds in 47
C.
Campbell, M. R., work cited 1
Cannon mine, King County, mining at 21
Carbonado formation, Carbon River field, coal beds in 43
Carbonado mine, Pierce County, gangway and chute system tried in, figure showing 52
  use of longwall system in 55, 56
Carbon mine, King County, plane system in 26
Carbon River district, Pierce County, features of 42–44
  geology of 43–45
Cedar River district, King County, features of 18
Chute and pillar system, at Taylor mine, King County 32
  figure showing 34
  in King County 27
  figure showing 27
  in Lewis County 13
  figure showing 13
  in Pierce County 51–54
  figure showing 52
Page.
Coal, output per man per day 73
  preparation of, in Lewis County 14
  in Tono mine 9
  production, data on 2, 73–75
Coal beds in Pierce County, relation of 44–46
Coal Creek mine, King County, coal beds at, figure showing 20
Coal fields and coal mines of Washington, location of, map showing 2
Coal mines in State, number of 2
Coals in State, quality of 1
Cokedale district, Whatcom County, mining in 15
Coking coals, location of, map showing 2
  in Pierce County 49
Costs of mining and preparing coal 68–72
D.
Doors, use of in Pierce County mines 57
Drainage, in King County mines 37
  in Tono mine 9
Durham, mining at 21
E.
Evans, G. W., work cited 19
Explosives, kinds used in King County mines 39
  in Lewis County mines 14
  in Pierce County mines 57
  in Roslyn field 65
  kinds used in mines in State 2
F.
Fairfax mine, Pierce County, operations at 46
Fay, A. H., work cited 74, 75
Fieldnar, A. C., work cited 1
Franklin mine, King County, figure showing 17
  mining at 20
Franklin series, coal beds of 19
G.
Gangways, cost of driving, in Pierce County 49
  driving of, in King County 23
  in Pierce County 49
  in Roslyn field 63
  figure showing 63
  timbering of, figure showing 23, 24, 29
  ventilation of, figure showing 30
Green River district, King County, features of 18
  mining in 20, 21
H.
Haulage methods in King County mines 38
  in Tono mine 8
Hiawatha, mining at 21
Hyde mine, King County, mining at 21
I.
Issaquah, coal beds at 17
K.
Kangley, King County, mining at 21
  coal fields and mines in, map showing 16
  mining costs in 70, 71
  mining methods in 22, 24–42
  subbituminous field, extent of 16, 17

Page.

- Kittitas County, coal fields and mines in 58–60
  - map showing 59
    - topography of 59
  - mining costs in 69
  - mining methods in Roslyn field 61–66
- Klansnick, Joseph, man-car invented by 42
- Kummer mine, King County, coal mining at 17
- Kummer series, coal beds of 19

L.

- Lewis County, coal beds in, geology of 5
  - coal fields and mines in, map showing 4
    - topography of 3
  - coal mine in 3
  - coals in, character of 5
  - mining costs in 69
  - subbituminous coal in, extent of 9
    - mining of 10–15
- Longwall system, use of, in King County 35
  - figure showing 36
  - in Pierce County 55, 56
- Lord, N. W., work cited 1

M.

- "McGinty" used in Roslyn field, figure showing 65
- McKay bed, King County, character of 19, 20
- Man cars, use of, at Black Diamond mine 42
  - in King County 42
- Melmont formation, Carbon River field, coal beds in 45, 46
- Melmont mine, Pierce County, operations at 46
- Miller coal bed, Pierce County, mining of 44
- Mine accidents, data on 75
- Mine doors, use of, in King County mines 40
- Mine fires, causes of, in King County 40, 42
  - Lewis County 14
- Mine haulage in Roslyn field 66
- Mine lighting in Roslyn field 67
- Miners' wages, scale of 72, 73
- Mining costs, in King County 70, 71
  - in Kittitas County 69
  - in Lewis County 69
  - in Pierce County 71, 72
- Mining machines, use of, in King County mines 39

N.

- National mine, King County, mining at 21
- Navy mine, King County, mining at 21
- Newcastle, King County, coal beds at 17
- Nisqually Chief coal bed, Pierce County, thickness of 47
- Nisqually district, Pierce County, features of 46, 47

O.

- Occidental mine, King County, mining at 21
- Overcasts, mine, construction of, in Pierce County 57
- Ovitz, F. K., acknowledgements to 3

P.

- Pierce County, coal fields and mines in 42
  - map showing 43
  - mining costs in 71, 72
  - mining methods in 48–58

Page.

- Pillar drawing, methods of, in King County 30–32
  - in Roslyn field 66
  - in Tono mine 8
- Plane system used in Lewis County 12
  - in Renton mine 26
- Pocahontas mine, King County, mining at 21

R.

- Raging River district, King County, features of 17
- Ravensdale mine, King County, mining at 20
- Renton mine, King County, plane system in 26
- Rice, G. S., acknowledgements to 3
- Room and pillar system used at Tono mine 7
  - in Lewis County 11–13
    - figure showing 12
- Rooms, mining of, in Roslyn field 64
  - figure showing 64
- Roslyn bed, Kittitas County, coals from, quality of 60
  - mining of, methods of 61–66
  - figure showing 62, 64, 65
- Roslyn-Cle Elum field, Kittitas County, geology of 60
  - importance of 58
  - map showing 58
  - topography of 59
- Roslyn formation, Kittitas County, coal beds in 60

S.

- Saunders, E. J., work cited 2
- Slopes, opening of, in King County 24–26
  - figure showing 25
  - timbering of, in King County, figure showing 26
- Smith, E. E., work cited 2
- Smith, G. O., work cited 58
- Smith, R. W., acknowledgments to 3
- Snoqualmie, King County, coal mining at 17
- Stoppings, construction of, in King County mines 40
  - in Pierce County mines 57
  - in Roslyn field 67
- Stream channels, preglacial, in King County, danger from 38
- Subbituminous coal, in King County, location of, map showing 16
  - quality of 22
  - in State, location of, map showing 2
  - in State reserves of 1
- Subsidence, surface, in King County 35

T.

- Taylor, coal mining at 17
- Taylor mine, King County, chute and pillar system in 32
  - figure showing 34
- Thurston County, coal fields and mines in 3
  - figure showing 4
  - coals in, character of 5
  - geology of 5
- Timber, use of, in King County mines 39
  - in Pierce County mines 57
  - in Roslyn field 66
  - in Tono mine 9

Page.
Tono mine, Thurston County, mining methods at 5-10
    figure showing 7
Transportation difficulties in Pierce County. 48
Tunnels, mine, driving of, in King County... 24

V.

Ventilation, mine, in King County 39
    figure showing 41
  in Lewis County 14
  in Pierce County 57
  in Roslyn field 67
  in Tono mine 8

W. Page.

Wages, *See* Miners' wages.
Whatcom County, anthracite coal in 15
  coal beds in 15
  coal mining in 15
Wilkeson formation, Carbon River field, coal beds in 44
Wilkeson mine, Pierce County, chute and pillar system in, figure showing.... 53
Willis, Baily, work cited 44
Wingate mine, Pierce County, workings in, figure showing 51